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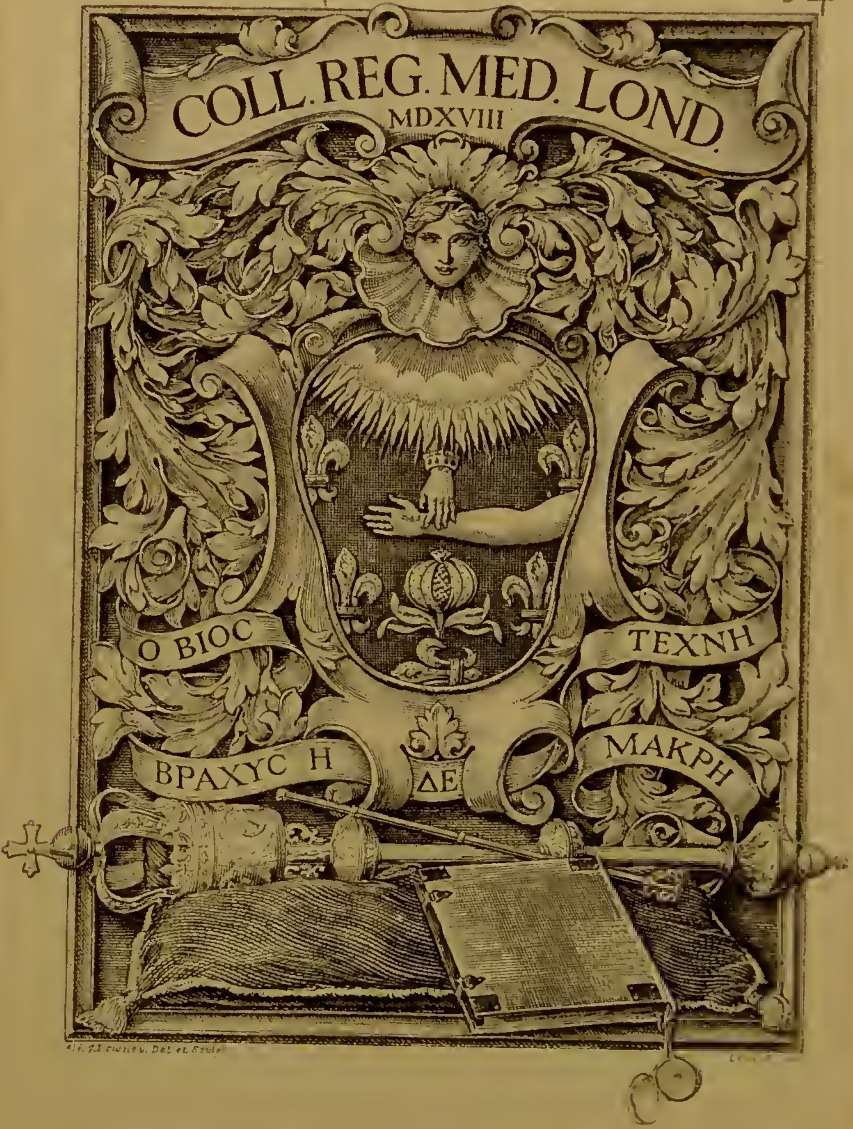

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THE

FIRST PRINCIPLES

OF

CHEMISTRY.

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OF

CHEMISTRY.

BY

WILLIAM NICHOLSON.

THE SECOND EDITION, WITH IMPROVEMENTS.

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PREFACE.

I HAVE ſpared no pains in collecting materials for the Treatiſe I now preſent to the world: I have condenſed thoſe materials into one volume, with more labour than I might have employed in diſtributing them into two or three: and I have printed it on a page unuſually full, at the ſame time that I have revived an ancient and uſeful practice of annexing ſide notes and references; which I believe has fallen into neglect, becauſe it requires great care in the author, uncommon attention in the printer, and adds to the expences incurred by the publiſher.

If the work ſhould not therefore prove to be ſo uſeful as my intention deſigned it, the defects will have ariſen chiefly from a want of that ability, which he who has it not, can by no exertion attain. The attempt itſelf is a proof, however, that I indulge expectations of a very different kind.

I believe I ſcarcely need remind the man of ſcience, that the great number of labourers in the chemical examination of bodies, has rendered it a difficult taſk to collect the various facts, which lie diſtributed in the acts of academies, and a variety of literary journals. It is not very eaſy to procure theſe books: and the peruſal of them produces a voluminous table of references; in which ſome things may be overlooked, even when noted. A certain degree of imperfection muſt ariſe, in every general treatiſe, from this cauſe. I have endeavoured to diminiſh it as much as poſſible.

In treating of facts long ſince eſtabliſhed, and ſuch whoſe diſcoverers are unknown to me, I have not quoted my authors; for, though I would gladly do juſtice to all claims, yet the inveſtigation of chemical hiſtory is foreign to the object of my preſent purſuit. Whenever I have quoted, it is to be underſtood that the authors are worthy of credit and reſpect; and that the reader will, in almoſt every inſtance, find his advantage in conſulting them for a fuller account of the ſubject. But I have quoted theſe only when it appeared neceſſary either to complete the information intended to be conveyed, or to clear myſelf from ſeeming to lay claim to their diſcoveries.

With regard to nomenclature and theory, I have attempted to keep clear of every ſyſtem. I have called things by ſuch names as are moſt in uſe, except where the uſual name pointed too evidently at theories either long ſince exploded, or not yet proved: and in the relation of facts I have found it much leſs difficult to exclude theoretical alluſions than I at firſt apprehended, when I formed the determination of confining the theory, for the moſt part, to the ends of chapters. It would be very advantageous to ſcience if this reſolution, which I have adhered to with my beſt endeavours, were more generally adopted. I do not, however, wiſh to be thought blind to the advantages of an uniform nomenclature, or a conſiſtent theory; but muſt urge my conviction that the former ought to be founded on the moſt incontrovertible facts only, becauſe the nomenclature of any mere theory may be productive of worſe conſequences than the moſt confuſed ſet of terms can poſſibly occaſion. The ſyſtemizing of words, inſtead of things, is the fruitful ſource of paralogiſm; and it is by falſe reaſoning of this kind that a well-methodized hypotheſis may be ſupported, long after the pretended facts are overthrown upon which it was originally built. Upon the two theories of chemiſtry I have ſpoken like one who admits neither in any other way than as probable ſuppoſitions, which have not yet been experimentally eſtabliſhed. The logic of the managers of the controverſy for and againſt phlogiſton, appears to me to be exceedingly defective in a great number of inſtances. The exiſtence of this chemical element is indeed very far from being well aſcertained; but, on the other hand, there are many difficulties which attend the conſideration of chemical facts without it. As I think the anti-phlogiſtic hypotheſis equally probable with the modified ſyſtem of Stahl, and more eſpecially as the excellent works of a number of French chemiſts are written in the language of that hypotheſis, I have judged it proper to explain both. And this I have endeavoured to do in ſuch a way, as to create in the chemical ſtudent an habit of ſteadily and calmly attending to the operations of nature; inſtead of indulging that haſty diſpoſition for theorizing, which indeed might paſs, on account of its evident impropriety, without any earneſt cenſure, if we had not the mortification to ſee it too much practiſed by men entitled to the beſt thanks of the ſcientific world, and on that account poſſeſſing greater power to miſlead.

London,
Jan. 25, 1790.

I HAVE carefully reviſed the ſecond Edition of this Work: the new diſcoveries are inſerted; and no exertions have been ſpared to render it worthy of the diſtinguiſhed approbation it has met with.

London,
Nov. 10, 1791.

CONTENTS.

BOOK I.

GENERAL CHEMISTRY.

CHAP. I. General Obſervations on Chemiſtry, and the Means by which its Operations are performed. — — — Page 1

CHEMISTRY defined. Analyſis. Syntheſis. Heat. Analyſis by heat. Attraction. Chemical attractions—act by means of heat. Art of the chemiſt. Elective attractions. Dry and humid way. Terms of art.

CHAP. II. Of Heat. — 5

Of the word Heat. Temperature. Cauſe of temperature. Common temperature. Conductors of heat. Solid, fluid, and vaporous ſtates. Expanſion. Changes by heat do not follow the denſity, &c. of bodies. Irregularities. Elaſtic fluids. Quantity of heat in equal bodies: — differing in temperature — in unequal bodies. Quantities required to change temperature. Thermometer:—its requiſites. Mercurial thermometer. Correſpondence of the expanſions of mercury with the increments of heat aſcertained by De Luc: — by Crawford. Quantities of heat in bodies of different kinds: — relative: — abſolute. Example. Comparative heat. Capacity. Capacities in various ſtates — changes by chemical actions. Inferences. Ice and water. Stationary temperature, or freezing point. Natural zero of temperature. Capacity of ſteam. Boiling-water point of temperature. Evaporation produces cold. Freezing by evaporation. Freezing mixtures. Fixed temperature of freezing mixtures.

mixtures. Freezing proceſſes by diſſolving ſalts in water. Mixture of ſalts for freezing water. General view of the agency of heat. Advantages ariſing from the changes of capacities. Whether heat be matter or motion. The philoſophy of heat admits no analogy. Diminution of capacity increaſes weight.

Chap. III. The Conſtruction of the Thermometer. — — 23

Conſtruction. To determine the cylindrical form of the tube. Method of blowing thermometers. Filling with mercury. Boiling the mercury in the tube. Caution. Trial of the proportion between the bulb and the tube. Hermetical ſealing of the tube. Proof of internal vacuum. Adjuſtment of the fixed points. Freezing. Boiling. Adjuſtment for errors of the tube. Standard thermometer. Caſes in which the mercury need not be boiled. Scales of thermometers. Fahrenheit's. Reaumur's. Celſius's. Reduction of degrees of thermometers of various ſcales.

Chap. IV. On Combuſtion, and the Application of Heat to chemical Purpoſes. — 32

Heat produced by friction; hammering; flint and ſteel; the ſolar focus; chemical mixtures; and by combuſtion. Proceſſes by heat. Roaſting; calcination; fuſion; digeſtion; cementation; evaporation; concentration; diſtillation; rectification; ſublimation. Flowers. Sublimates. Inſtruments. Crucibles; cucurbits, or matraſſes; retorts; receivers; alembic — of glaſs; — of metal. Stills for ardent ſpirit. Furnaces. Melting furnace; reverberatory furnace. Fuel. Chemical bath. Coating. Lutes. Fat lute. Lamp. Facility of making experiments. Moveable furnaces — for open fire — wind furnace — reverberatory furnace — blaſt furnace. The blow-pipe. Artifice of blowing through it. Flame urged by the blow-pipe. The ſubject to be heated. Advantages of this inſtrument: — its uſe rendered eaſy by bellows. Blow-pipe with vital air.

Chap. V. Concerning the Methods of making Experiments on Bodies in the Fluid and in the Aeriform State. — — 47

Apparatus for denſe fluids — for elaſtic fluids. Body and tube. Stand or ſupport of wire. Gun-barrel. Phials with quickſilver. Burning lens, or mirror. Apparatus with mercury.

Combuſtion of air. Meaſuring tubes. Eudiometers. Management of powders. Electric ſpark. Holes drilled in glaſs. Impregnation of water with fixed air. Dr. Nooth's apparatus: — its valve defective. Improvements in diſtillation. Combination of receivers. Improved receiver. Remedy againſt abſorption.

Chap. VI. Concerning the Balance and Weights, with a Comparative Table of the various Weights made uſe of in Europe. — — 59

Balance deſcribed. Points of ſuſpenſion. Fulcrum. Propoſitions. Weighing with a balance which is not equibrachial. Conſtruction of the balance. The turn. Accurate weighing is ſlow. Long beams. Sets of weights. Common pile. Biſection. Wire rings. Number of weights required to form a ſet. Decimal ſet of weights. Account of ſome balances. The balance of Muſchenbroek:—of Bolton: —of Mr. Read:—of Mr. Whitehurſt:—of the Author:—of Mr. Alchorne:—of Dr. Geo. Fordyce:—of Mr. Magellan:—of the Royal Society. Inferences. Compariſon of weights:—by Monſ. Tillet.

Chap. VII. On the Attractions exerted between Bodies; particularly thoſe which the Chemiſts call Elective Attractions. —— 71

Great importance of the knowledge of the actions between the parts of bodies. Inertia of matter. Extenſion. Gravity may perhaps be modified:—but is not found to vary in experiments. Uſual inference. Effects of attraction. Coheſive attraction differs from gravity. Elective attraction:—does not depend on denſity—probably on figure. Aggregation. Mixture. Combination, or compoſition. Integrant and component parts. Elements, or firſt principles. Simple combination. Suſpenſion. Solvent, or menſtruum. Water. Cauſe of error in eſtimating the attractions. Limits of ſaturation:—in fluids: — in general. Solution aſſiſted by heat. Medium of combination. Separation, or precipitation. Simple elective attraction. Examples:—in the humid way:—in the dry way. Conjectural inference. Double elective attraction. Example: in the humid way:—in the dry way. Numerical expreſſion of affinity. Mechanical properties of bodies do not follow the properties of their component parts. Utility of theſe changes. Cryſtallization. Polarity of the particles of bodies.

BOOK II.

PARTICULAR CHEMISTRY.

SECTION I.

OF THE GENERAL PRINCIPLES OF BODIES.

CHAP. I. Concerning the General Diviſion of Chemical Principles. — 83

Arrangement. Enumeration. Animal, vegetable, and mineral kingdoms.

CHAP. II. Concerning Heat, Light, and Phlogiſton, conſidered as Component Parts of Bodies. — —— 87

Heat. Light. Subtle fluid. Light and heat differ. Phlogiſton. Queſtion concerning this principle.

CHAP. III. Of Phlogiſticated, Dephlogiſticated or Vital, and Inflammable Air, and of the Compoſition and General Properties of Water. 92

Effects of combuſtion on common air. Obſervations and Opinions. Compoſition of the atmoſphere. Subſtances which afford vital air. Reſpiration is a proceſs of the ſame kind as combuſtion. Vegetables affect the air. Nitrous air uſed as a teſt. Subſtances which afford inflammable air. Water produced by combuſtion of vital and inflammable air. Whether water be a compound:—its extenſive utility—and general properties. Effects of the colipile. Denſity of water. Specific gravity of water. What waters are pureſt.

CHAP. IV. Of the Simple or Primitive Earths. 99

Five primitive earths. New earths. Stones. Siliceous earth. Liquor of flints. Argillaceous earth. Earth of alum. Pottery. Wedgwood's thermometer. Calcareous earth. Lime. Mortar. Plaſter of Paris. Animal earth. Ponderous earth. Spar.

Magneſia. Epſom ſalt. Union of earths by fuſion. Suppoſed reduction. The new earths—of adamantine ſpar—of the Jargon of Ceylon—of a mineral from South Wales.

CHAP. V. Of the Simpler Salts; namely, Alkalis and Acids. —— 108

Characters of alkalis. Vegetable fixed alkali. Methods of procuring it. Purifying of alkalis. Alkali of nitre, called fixed nitre. Oil of tartar. Mineral alkali. Water of cryſtallization. Effloreſcence. Abundance of mineral alkali in ſea ſalt:—obtained by incineration. Turner's proceſs with common ſalt. Cauſtic ſolution of alkali:—or ſoap lees. Soap. Manufacture of ſoap in the large way. Manufacture of glaſs. Difficulties. Manufacture of ſal ammoniac. Volatile alkali:—obtained by the medium of chalk:—obtained by the medium of lime. Alkaline air. Decompoſition and formation of volatile alkali. Characters of acids. Enumeration. Mineral acids. Vegetable acids. Animal acids. Inflammable additions to acids. Theory. Neutral ſalts.

CHAP. VI. Of Metallic Bodies in general. 120

Characters of metals. Entire metals. Perfect and imperfect metals, Calces. Enumeration of metals. Regulus. Freezing point of metals. Cryſtallization. Affinities. Solder. Countries moſt abundant with metals. Ores. Veins. Mines. Matrix. Operations for extracting metals from ores. Aſſaying, or eſſaying. Humid way. Theory. Mixture of metals. Alloys. Solubility of metals in acids. Precipitation. Inferences. Original theory. New theory. Precipitation of metals by metals. Limit of ſolution in acids. Theory of ſolution. Action of various ſubſtances on metals.

SECTION II.

CONCERNING THE MINERAL ACIDS, AND OTHER MINERAL BODIES WHICH ARE CONVERTIBLE INTO ACIDS.

CHAP. I. Of Sulphur, Vitriolic Acid, and the Combinations they form with other Bodies. 129

Sulphur. Pyrites. Diſtillation of ſulphur:—ſublimation. Action of water on ſulphur. Combination of ſulphur; with lime:—with ponderous earth:—with magneſia:—with fixed alkalis. Hepatic air. Volatile liver of ſulphur. Balſams. Combuſtion of ſulphur. Volatile vitriolic acid. Oil of vitriol. Vitriol of iron. Diſtillation of vitriol. Manufacture of vitriolic acid. Characters. Combination of vitriolic acid and clay. Preparation of alum. Vitriolic acid with lime:—with ponderous earth:—with magneſia:—with vegetable alkali:—with mineral alkali:—with volatile alkali:—with combuſtible matter. Aeriform vitriolic acid. Sulphureous acid. Characters of vitriolic acid air. Stahl's experiment for obtaining ſulphur from vitriolic acid. Electricity. Recapitulation and theory.

CHAP. II. Of the Nitrous Acid, its component Parts and Combinations. 145

Production of nitre. Nitre beds. Extraction and purification of nitre. Decompoſition by heat. Deflagration. Detonation. Invention of gunpowder:—its compoſition. Fulminating powder. Diſtillation of nitrous acid. Combination with lime:—with ponderous earth:—magneſia:—and clay:—with mineral alkali:—with volatile alkali. Production of nitrous acid:—by Mr. Cavendiſh:—by M. Thouvenel. Inference. Action of nitrous acid upon combuſtible matter. Nitrous air. Dr. Prieſtley's method of aſcertaining the reſpirability of air. Imperfections of the trial of air by nitrous air. Eudiometers. Action of nitrous acid on animal ſubſtances. Various fluids imbibe nitrous acid. Diminution of nitrous air by electricity, &c. Dephlogiſticated nitrous air. Abſorption of nitrous air by the nitrous acid. Pale nitrous acid becomes yellow by the action of light:—it is capable of the elaſtic form. Inflammation of eſſential oils by nitrous acid:—of fat oils:—of charcoal or lamp black. Recapitulation and theory. Keir's compound acid.

CHAP. III. Of the Marine Acid, and its Combinations, including Aqua Regia. 170

Salt mines and ſprings. Sea water. Extraction of common ſalt from waters. Various methods of obtaining ſalt from the waters of the ſea and ſalt ſprings. Salts contained in the ſea. Cryſtallization of common ſalt. Diſtillation of marine acid from common ſalt. Marine acid air—its corroſive nature. Salt of Sylvius. Sal ammoniac. Marine ſelenite. Homberg's phoſphorus. Argillaceous marine ſalt. Ponderous marine ſalt. Magneſian marine ſalt. Action of marine acid upon metals. Dephlogiſticated or aerated marine acid. Detonating marine ſalt:—with baſe of vegetable alkali:—with mineral alkali:—volatile alkali. Action of light on dephlogiſticated marine acid. Theory. The acidity of marine acid does not vary after the law of other acids. Compoſition of aqua regia. The effects and theory of aqua regia. Combinations.

CHAP. IV. Of Fixed Air, Fixable Air, or Aerial Acid. — 183

Subſtances which contain fixed air. Impregnation of water. Grotto del Cano. Fixed air emitted from fermenting bodies. Experiments made in an atmoſphere of fixed air. Converſion of vegetable matter into charcoal. Production of fixed air from charcoal. Compoſition of fixed air. Opinions. The electric ſpark paſſed through fixed air. Phlogiſtic explanation. Antiphlogiſtic explanation. Combinations of fixed air:—with clay:—with calcareous earth:—with ponderous earth:—with magneſia:—with alkalis:—with combuſtible matter. Advantages derived from a knowledge of this acid.

CHAP. V. Of the Acid of Borax. 191

Natural production of tincal or crude borax. Purification. Analyſis. Habitudes. Acid of borax:—found native. Analyſis of the native combination of the acid of borax with lime and magneſia. Combinations of the acid of borax with earths and alkalis. Suppoſed reduction to the metallic form.

CHAP. VI. Of the Acid of Spar. 196

Fluor or Derbyſhire ſpar;—its acid:—diſſolves ſiliceous earth. Etchings on glaſs. Combinations with earths, alkalis, and metals.

CHAP. VII. Of the Acid of Amber. 198

Characters of amber:—where found. Combinations of the acid of amber.

CHAP. VIII. Of Phoſphorus and its Acid. 200

Native phoſphorus. Characters of phoſphorus. The diſcovery of phoſphorus; by Brandt, Kunckel, and Boyle. Defence of Boyle as the inventor. Proceſs of Boyle. Proceſs for obtaining phoſphorus from bones. Phoſphoric glaſs. Purification of phoſphorus. Phoſphoric acid, obtained by ſlow combuſtion. Concrete phoſphoric acid. Phoſphoric acid obtained by the action of nitrous acid:—by vitriolic acid:—by ſtrong combuſtion:—by a ſtream of vital air. Phoſphoric hepar, and air. Combination of phoſphorus with ſulphur:—with oils:—ardent ſpirits:—metals. Metals revived by phoſphorus. Uſes of phoſphorus. Phoſphoric matches. Two ſtates of phoſphoric acid. Combinations of phoſphoric acid with earths and alkalis. Phoſphoric ſalts from urine. Microcoſmic ſalt. Perlate acid. Combinations of phoſphoric acid with metals and oils. Theory.

Chap. IX. Of the Metallic Acids; of Arſenic, of Molybdena, and of Tungſten or Wolfram. 211

Retroſpect of the facts and doctrines contained in the preſent ſection. Acidification of metals. General inferences, by conjecture. Arſenical acid. Proceſs for obtaining it. Characters. Combination with earths:—with alkalis. Reduction. Combination with ſulphur. Theory. Characters of molybdena. Proceſs for obtaining its acid. Combinations. Regenerated molybdena. Acid of tungſten, or wolfram. Proceſs for obtaining it. Characters.

SECTION III.

OF METALLIC BODIES.

Chap. I. Concerning Gold.

Characters of gold. Obvious properties. Extreme ductility and tenacity. Manufacture of gold leaf:—its thickneſs. Gilt wire. Solvents. Aqua regia. Solution of gold. Precipitates:—by earths and alkalis:—volatile alkali. Production of fulminating gold. Analyſis. Theory. Precipitation of gold by liver of ſulphur:—by metallic ſubſtances. Proceſs for making the purple powder of Caſſius. Obſervations. Solution of gold in ether, &c. Gold reſiſts nitre:—but is rendered pale by borax:—unchanged by earths, alkalis, or ſulphur. Proceſs of dry parting. Combination with liver of ſulphur:—with metals. Native ores, or alloys of gold. Auriferous ſands. Pyrites containing gold. Cupellation. Separation

tion of gold from the perfect metals:—by quartation:—and parting. Fineneſs of gold. The aſſay of ſmall work by the touch. Touch-needles. Obſervations on the aſſay by the touch. Aſſay of gold ores in the moiſt way. Uſes of gold.

Chap. II. Concerning Silver. 236

Characters of ſilver. Solubility in acids. Combination with nitrous acid. Lunar cauſtic. Vitriol of ſilver. Luna cornea. Malleable glaſs. Very pure ſilver obtained from luna cornea. Teſt of marine acid in waters. Purification of nitrous acid. Precipitates. Preparation of fulminating ſilver. Its effects. Precautions. Theory of the inventor. Phlogiſtic theory. Action of Keir's compound acid upon ſilver—of aqua regia. Precipitation by metals. Proceſs of Lemery for making the tree of Diana. Homberg's proceſs. Theoretical obſervations. Combinations with metals. Native ſilver and its ores. Purifying of native ſilver. Vitreous ore of ſilver. Analyſis in the moiſt way:—in the dry way. Red ſilver ore. Analyſis in the moiſt way. White ore of ſilver analyſed. Method of aſſaying ſilver, or its ores, in the dry way. Aſſay of ſilver by the touch. Extraction of ſilver from ores in the large way, by amalgamation:—by fire. Uſes of ſilver.

Chap. III. Concerning Platina. 251

Characters of platina. Crude platina. Pure platina. Welding. Solution in dephlogiſticated marine acid:—in aqua regia. Diſtinctive character. Separation of gold from platina. Malleable platina. Precipitates. Crucibles of platina. Combinations of metals. Cupellation.

Chap. IV. Concerning Mercury. 256

Characters of mercury. Precipitate per ſe. Electric light. Action of vitriolic acid. Vitriol and calx of mercury. Turbith mineral. Precipitates. Solution in nitrous acid. Nitrous turbith. Mercurial nitre. Red precipitate:—decompoſed. Precipitates. Exploſion of mercurial precipitates. Decompoſition of the nitrous ſolution by other acids. Corroſive ſublimate. Calomel. Combination of mercury with dephlogiſticated marine acid. Preparation of corroſive ſublimate. Cauſticity of metallic ſalts. Sal alembroth. White precipitate. Preparation of calomel, or mercurius dulcis. Butter of antimony. Mercurial ethiops. Cinnabar or vermilion formed in the dry way:—in the humid way. Unguents, &c. Red calx of mercury, or precipitate per ſe. Amalgams. Combinations of metals. Native mercury and its ores. Decompoſition of cinnabar. Purity of mercury. Humid analyſis of cinnabar. Uſes of mercury.

CHAP. V. Concerning Lead. 268

Characters of lead. Granulated. Calcined. Minium, or red lead. Litharge and glaſs of lead. Achromatic teleſcope. Action of air and water on lead :—of vitriolic acid. Combination of nitrous acid and lead. Plumbum corneum. Action of marine acid :—acetous acid. White lead, or ceruſe. Sugar of lead. Action of liver of ſulphur on lead :—of alkalis :—oils. Habitudes in the dry way :—with phoſphoric acid. Decompoſition of ſal ammoniac :—of common ſalt. Combinations of lead with metals. Eliquation. Plumber's ſolder. Fuſible mixture. Native lead and its ores. Analyſis of calciform ores. Native ſalts of lead. Humid analyſis of phoſphoric lead ore. Sulphureous ore of lead, or galena. Analyſis of ſulphurated lead. Revival of lead by the blow-pipe. Uſes of lead.

CHAP. VI. Concerning Copper. 278

Characters of copper. Solution in vitriolic acid. Nitrous ſolution of copper :—marine :—vegetable. Effect of the preſence of air. Fabrication of verdigris. Solution of copper in fixed alkalis :—in volatile alkali. Habitudes of copper with volatile alkali :—with oils, earths, alkalis, and neutral ſalts :—with ſal ammoniac :—with alum :—with ſulphur :—with phoſphorus :—with metallic ſubſtances. Bronzes and bell-metal. Metal for ſpeculums. Edwards's method of making ſpeculums. Metallic mixtures. The fabrication of braſs. Leaf braſs, or Dutch gold. Native copper, and its ores. Aſſay of native copper :—of calciform ores :—of ſulphureous ores :—in the dry way. Treatment of copper ores in the large way. Countries where copper is found. Copper applied to various uſes.

CHAP. VII. Concerning Iron. 293

Characters of iron. Calcination of iron by water. Ancient theory. Modern theory. Solution in the vitriolic acid. Martial vitriol. Theory of the effects of vitriolic acid upon iron :—according to the doctrine of phlogiſton :—according to the antiphlogiſtic doctrine. Precipitates of iron. Colcothar. Black fecula, precipitated by aſtringents. Ink; its nature doubtful. Manufacture of Pruſſian blue. Pruſſian alkali. Acid of Pruſſian blue. Combinations of Pruſſian acid. Caution in uſing proof liquors. Experiments on Pruſſian acid. Theory of the effects of aërated marine acid on the Pruſſian acid. Experiment. Component parts of Pruſſian acid. Action of nitrous acid on iron. Precipitates of iron from nitrous acid. Martial alkaline tinctures. Action of marine acid on iron. Precipitates. Action of fixed

air and vinegar. Action of earths, &c. on iron. Combination with ſulphur, in the humid way. Spontaneous inflammation. Theory of the inflammation of iron and ſulphur: — by the antiphlogiſtic hypotheſis. Union of ſulphur with iron in the dry way, Phoſphorus and iron. Cold ſhort iron. Siderite. Metallic combinations. Tinning of iron plates. Combinations of iron with metallic ſubſtances. Native iron and its ores. Humid analyſis of iron ores. Analyſis in the dry way. Smelting of iron in the large way. States of iron. The three kinds of crude iron. Refining of iron. Bar iron. Iron converted into ſteel by cementation. The proceſſes for hardening and tempering of ſteel. Caſt ſteel. Compariſon of ſteel and crude iron. Conſideration of the effects of heat in refining iron. Probable cauſe of the property of welding. Proceſſes for refining crude iron, and making ſteel in a direct way. The exiſtence of plumbago in crude iron and ſteel; aſcertained in the dry way. Plumbago extricated from iron in the humid way. Quantities of plumbago and of inflammable air afforded by various kinds of iron. Degrees of reduction and cementation in iron. Inaccuracies. Characters of plumbago:—habitudes. Experiments tending to diſcover the component parts of plumbago. Phlogiſtic theory, Antiphlogiſtic theory of plumbago. Reſemblance between plumbago and pyrites. Recapitulation of the facts relating to the ſtates of iron. Uſes.

Chap. VIII. Concerning Tin. 334

Characters of tin. Solution in vitriolic acid:—in nitrous acid. Singular effect. Volatile alkali produced from nitrous acid, &c. Solution of tin in marine acid:—in dephlogiſticated marine acid: —in aqua regia. Acid of tin. The fuming liquor of Libavius. Adet's examination of the fuming liquor. Habitudes of tin with earths and neutral ſalts: — with ſal ammoniac. Spontaneous decompoſition and inflammation of metallic ſalts. Combination of tin with ſulphur. Aurum muſivum. Combination of tin with phoſphorus. Metallic mixtures. Pewter. Miſtake of foreigners reſpecting Engliſh tin. Native tin. Calciform ores of tin. Tin ores containing arſenic and ſulphur. Proceſs of elutriation deſcribed and explained. Putty. Analyſis of tin ores, in the humid way:—in the dry way. Reduction of tin in the large way. Countries which afford this metal. Uſes.

Chap. IX. Concerning Biſmuth. 349

Characters of biſmuth. Action of vitriolic acid. Solution in nitrous acid. White calx or magiſtery of biſmuth. Solution in marine acid. Habitudes with earths, ſalts, ſulphur, and metallic ſubſtances. Uſes. Native biſmuth and its ores.

Chap. X. Concerning Nickel. 353

Characters. Treatment of the ores of nickel. Pureſt regulus of nickel:—is an entire metal. Action of vitriolic acid. Whether nickel be truly a peculiar metal.

Chap. XI. Concerning Arſenic. 356

Characters. White calx of arſenic:—is in a ſaline ſtate. Regulus. Action of vitriolic acid:—of nitrous acid:—of marine acid:—of aërated marine acid. Diſtillation of calx of arſenic with ſulphur. Orpiment and realgar. Liver of ſulphur. Combination of calx of arſenic with alkalis:—with metals. Action of arſenical acid on metals. Combinations of regulus of arſenic. Uſes of arſenic.

Chap. XII. Concerning Cobalt. 366

Characters of cobalt. Combination with vitriolic acid:—with nitrous acid:—with marine acid:—with aqua regia. Sympathetic ink. Acid of borax and cobalt. Acid of ſugar. Habitudes of cobalt:—with nitre:—with ſal ammoniac:—with ſulphur:—with metallic ſubſtances. Native cobalt and its ores. Humid analyſis. Analyſis in the dry way. Cobalt found moſt plentifully in Saxony. Manufacture of zaffre and ſmalt. Uſes of cobalt.

Chap. XIII. Concerning Zinc. 372

Characters of zinc. Solution in vitriolic acid. White vitriol. Solution of zinc in nitrous acid:—in marine acid. Habitudes with vitriolic ſalts:—with nitre:—with common ſalt, ſal ammoniac, and alum:—with ſulphur:—with liver of ſulphur:—with metals. Native zinc and its ores. Humid analyſis. Eſſay of calamines. Diſtillation of zinc. Spelter. Uſes.

Chap. XIV. Concerning Antimony. 378

Characters of antimony. Action of vitriolic acid.—nitrous acid:—marine acid:—dephlogiſticated or aërated marine acid:—aqua regia. Habitude of regulus of antimony with earths:—with vitriolated tartar. Detonation with nitre. Diſtillation of the regulus with corroſive ſublimate. Butter of antimony. Theory. Powder of algaroth. Bezoar mineral. Combination of regulus of antimony with ſulphur:—with liver of ſulphur. Crude antimony:—its habitudes:—by heat:—with acids. Diapho-

Diaphoretic antimony. Antimonial medicines. Kermes mineral. Emetic wine. Antimoniated tartar. Medical effects of antimony. Perpetual pills. Native antimony and its regulus. Humid analyſis. Dry way. Uſes.

Chap. XV. Concerning Manganeſe. 386

Characters of manganeſe. Action of vitriolic acid. Black calx of manganeſe. Theory. Solution of the regulus in nitrous acid:—in marine acid. Combinations of calx of manganeſe in the dry way. Explanation of the changes of colour in glaſſes which contain manganeſe. Theories. Combination with ſulphur. Metallic combinations of manganeſe. Native manganeſe and its ores. Humid analyſis. Spontaneous inflammation of black wadd. Reduction of manganeſe. Speedy calcination. Uſes.

Chap. XVI. Concerning Wolfram. 394

Characters and habitudes of the calx and regulus of wolfram.

Chap. XVII. Concerning Molybdena. 396

Characters of regulus of molybdena. Habitudes with various ſubſtances. Diſtinctive characters.

Chap. XVIII. Concerning Uranite, or Uranium. 398

Deſcription of pitch-blende. Habitudes with fire:—with acids. Yellow calx. Reduction.

SECTION IV.

OF MINERAL COMBUSTIBLE BODIES, AND THE DIAMOND.

Chap. I. Of Mineral Combuſtible Bodies. 401

Enumeration. Petroleum. Barbadoes tar. Aſphaltum. Mineral tallow. Jet. Pit coal. Peat. Turf. Amber. Sulphur. Plumbago. General obſervations on the combuſtible ſubſtances found in the mineral kingdom.

Chap. II. Concerning the Diamond. 405

Characters, &c. of the diamond. Hardneſs and brilliance of diamonds:—ſoluble in vitriolic acid:—combuſtible. Coloured diamonds.

SECTION V.

CONCERNING THE PRODUCTS OF THE VEGETABLE KINGDOM.

Chap. I. Of the Structure and Component Parts of Organized Subſtances. 409

General obſervations. The parts of organized bodies conſtitute apparatus for performing chemical operations. Vegetable bodies. Animal bodies. Secretions or combinations of vegetable and animal ſubſtances. Nutrition. Diſeaſe. Death. Various methods of ſeparating the parts of animal or vegetable ſubſtances. Vegetable products arranged.

Chap. II. Concerning ſuch Principles of Vegetables as do not exhibit Saline Properties, and are obtained without the Application of any greater Heat than that of Boiling Water, and without the Action of any Solvent but Water or Ardent Spirit. — — 416

Enumeration of ſuch principles of vegetables as are not ſaline. Juices or extracts. Mucilage or gum. Sugar. Manufacture of ſugar. Manufacture of flour, or the powder of farinaceous ſeeds. Starch. Vegetable gluten. Fat oils. Volatile or eſſential oils. Camphor. Reſinous ſubſtances. Principle of ſmell in vegetables. Colouring matters. Art of dying. Lakes.

Chap. III. Concerning the Saline Principles of Plants obtained by Preſſure, or by the Application of Water or Ardent Spirit; particularly the Acids of Lemons, of Apples, of Nut-Galls, and of Benzoin. — — 415

Mineral ſalts found in vegetables. Peculiar ſalts enumerated. Various methods of preſerving lemon-juice:—by oil:—by evaporation:—by freezing. Depuration of the acid of lemons: —by congelation: — by the chemical affinities. Characters. Method of purifying the acid of apples. Separation of the acids of lemons and of apples. Acid of apples. Characters. The aſtringent principle, or acid of galls:—obtained in ſolution:—in the cryſtallized form. General characters and habitudes of the acid of galls. Benzoin: — its acid obtained by ſublimation, and in the humid way:—its characters.

Chap. IV. Concerning the Acids of Tartar and of Sorrel. — 437

Tartar. Cream and cryſtals of tartar. Characters of purified tartar. Habitudes. Soluble tartar. Curious fact reſpecting ſolubility. Manufacture of Rochelle ſalt. Ammoniacal ſalt of tartar. Method of obtaining the acid of tartar:—its characters and habitudes. Salt of ſorrel: — its characters, and action upon various ſubſtances. Method of purifying the acid of ſorrel. Characters. Combinations.

Chap. V. Concerning the Vegetable Acids produced or developed by Deſtructive Diſtillation, or by the Action of Nitrous Acid. — 445

Conſiderations on the compoſition and decompoſition of vegetable bodies. Simplicity and ſmall number of vegetable principles. Empyreumatic acids. Empyreumatic acid of tartar:—of ſugar or mucilage:—of wood. Obſervations on the effect of nitrous acid upon vegetable bodies. The progreſs of acidification in vegetable bodies. Difference between the acids of ſugar and ſorrel. The proceſs for converting ſugar into an acid. Obſervation. Acid of camphor. Acid of cork.

Chap. VI. On the Deſtructive Diſtillation of Vegetable Subſtances. — 452

Deſtructive diſtillation. Decompoſition of vegetables by fire. Empyreumatic oils. Charcoal:—conducts electricity:—reſiſts heats, and abſorbs claſtic fluids :—exceedingly combuſtible :—ſolubility :—revivification. Obſervation. Reſidual ſalts.

Chap. VII. Concerning Fermentation in general. — 457

The ſpontaneous decompoſition of vegetables. Three ſtages of fermentation : — vinous : — acetous : — putrid. Conditions of circumſtances requiſite to the progreſs of fermentation. Vinous fermentation deſcribed, as it takes place in ſugar and water. Yeaſt. Inflammable ſpirit. Acetous fermentation. Putrefaction. The effect of yeaſt in fermentation. Component parts of ardent ſpirit, &c. Tartar. Bread.

Chap. VIII. Concerning Vinous Fluids and Ardent Spirit. — 463

The making of wine from grapes. The malting of barley :—of Indian corn. Brewing of beer. Metheglin and koumiſs. Product of vinous liquors by diſtillation. Reſidue. Strength of ardent ſpirit determined by M. Bories. Specific gravities of various mixtures of water and ſpirit. Obſervations. Strongeſt ardent ſpirit by mere diſtillation. Requiſites or deſiderata to aſcertain the ſtrength of ſpirit. Phial proof. Proof by burning. Characters and component parts of ardent ſpirit : — its uſes and combinations. Mutual action of ardent ſpirit and ſalts ;—and ſulphur :—and earths.

Chap. IX. Concerning thoſe Inflammable Fluids which are produced by the Action of Acids upon Spirit of Wine, and are known by the Name of Ether. — — — 472

Diſtillation of vitriolic ether. Rectification. Characters. Solubility in water. Combinations of vitriolic ether. Methods of preparing nitrous ether. Characters. Method of preparing marine ether. Acetous ether. Ligneous ether. Saccharine ether. Phoſphoric ether. Ether produced by acid of ants : —by acid of benzoin. General obſervations.

Chap. X. Concerning the Acetous Acid. 482

Crude vinegar. Diſtilled vinegar, or acetous acid. Concentration by froſt. The moſt advantageous method of concentrating vinegar. Combinations of acetous acid : — with argillaceous earth : — with calcareous earth : — with magneſia : — with vegetable alkali. Foliated earth of tartar. Radical vinegar. Combi-

Combinations of acetous acid : — with mineral alkali : — with volatile alkali : — with gold : — with ſilver : — with mercury : with lead :—with copper :—with iron. Metallic combinations. Zinc an improper material to defend copper veſſels.

SECTION VI,

CONCERNING THE PRODUCTS OF THE ANIMAL KINGDOM.

CHAP. I. A Short Enumeration of ſuch Animal Subſtances as have been examined by Chemiſts. — — — 489

Analyſis and arrangement. Enumeration.

CHAP. II. Concerning Milk, Eggs, Honey, Wax, Lacca, Silk, Hair, Horn, &c. 491

General characters of milk. Effects of heat on cows milk. Fermentation of milk. Cream. Butter. Acid of milk. Its combinations with various ſubſtances. Curd. Manufacture of cheeſe : — its properties. Sugar of milk : — decompoſed by heat :—treatment with nitrous acid. Peculiar acid of ſugar of milk. Combinations. Separation of butter from cream :— its properties. Eggs. Reſemblance between white of egg and curd of milk. Yolk of egg. Honey and wax. Purification of honey. Diſtillation of wax. Butter of wax. Bleaching. Difference between wax and tallow. An explanation of the chief advantage of wax candles compared with thoſe of tallow. The uſe and effects of the wick in candles. Stick-lac, ſhell-lac, and ſeed-lac : — its production : — purification : — characters. Hard varniſh. Uſes of lac. Silk, and the acid of ſilk-worms. Animal excreſcences.

CHAP. III. Concerning the Excrementitious Parts of Animals. — 506

Urine and fecal matter. Stone of the bladder. Acid of the ſtone of the bladder. Homberg's experiments on human excrement. Ambergris : — its characters. Matter of perſpiration, &c.

Chap. IV. Concerning the Blood, and the other Fluid or Solid Matters of which Animals are formed. — — — 510

Characters of the blood. Habitudes with acids, &c. Diſtillation. Serum of blood:—reſembles white of egg, curd, and vegetable gluten:—habitudes with alkalis and acids:—with ardent ſpirit:—with nitrous acid. Craſſamentum. Fibrous part of blood:—with acids. Deſtructive diſtillation. Soft parts of animals. Jelly or glue. Analyſis of the fleſh of animals. Animal fat:—its acid:—characters. Method of obtaining ſpermaceti. Its characters and habitudes. Conjecture reſpecting its ſingular properties. Bones:—their white reſidue.

Chap. V. Concerning the Bile, the Gaſtric Juice, and the Acid obtained from Ants. 520

Characters of the bile, or gall. Deſtructive diſtillation of the bile. Biliary concretions. The gaſtric fluid. Acid of ants.

APPENDIX.

VARIOUS TABLES USEFUL TO CHEMISTS.

Page
An Account of the Tables — — — 525
Table I. The Comparative Heats of different Bodies 533
Table II. The Weights of different Countries — 534
Table III. The Specific Gravities of Bodies — 535
Table IV. The Specific Gravities of Aerial Subſtances; the Barometer ſtanding at 30 Inches, and the Thermometer at + 55° — — — — — — 536
Table V. The Expanſions of Aerial Subſtances by Heat, from the Freezing to the Boiling Points of Water. For every Interval of 20° of Reaumur's, or 45° of Fahrenheit's Thermometer — — — — — *ibid.*
Table VI. Simple Elective Attractions.—Acids — 537
Table VII. Simple Elective Attractions.—Alkalis and Earths 538
Table VIII. Simple Elective Attractions.—Combuſtible Subſtances and Water — — — — 539
Table IX. Simple Elective Attractions.—Phlogiſton and Metals — — — — — 540
Table X. Simple Elective Attractions.—Metallic Subſtances 541
Table XI. Simple Elective Attractions.—Metallic Subſtances 542
Table XII. Numerical Expreſſion of Attractions by M. Morveau — — — — — 543
Table XIII. Of the Proportion of Ingredients in Earths and Stones.—Calcareous Genus.—Barytic or Ponderous Genus.—Muriatic or Magneſian Genus.—Argillaceous Genus.—Siliceous Genus.—Proportion of Ingredients in Natural Salts *ibid.*
Index — — — — 547

EMENDATIONS AND ADDITIONS.

I HAVE not obſerved any error of the Preſs but ſuch as the ſenſe of the context will obviouſly tend to rectify.

In the Chapter on Nitrous Acid I have omitted to inſert an account of the very important diſcovery of the Rev. Iſaac Miner, B.D. F.R.S. inſerted in the LXXIXth vol. of the Philoſophical Tranſactions. This gentleman, finding, as well from his own experiments as thoſe of others, that volatile alkali is afforded in various inſtances of the application of nitrous acid to metals (ſee page 336 of the following treatiſe), was almoſt immediately ſtruck with the notion, that the proceſs might be inverted. That is to ſay, as the phlogiſticated air of nitrous acid, when made to combine with inflammable air, affords volatile alkali; ſo, on the contrary, if vital air could, by any effect of the chemical affinities, be made to engage with the phlogicated air of volatile alkali, while the other principle, namely, the inflammable air, ſhould be either retained or diſengaged, the reſult of ſuch an engagement or combination would be the nitrous acid in ſome of its modifications. For this purpoſe, he crammed a gun-barrel full of mangancſe in coarſe powder, which ſubſtance is known to afford vital air by heat, and to one end of this tube he applied a retort containing the cauſtic volatile alkali. Heat was then applied to the gun-barrel, and, as ſoon as it was ignited, he placed a candle beneath the retort, which cauſed the volatile alkali to boil, and paſs through the gun-barrel in the form of alkaline air: the conſequence was, that nitrous air was emitted at the other end of the tube.

He likewiſe repeated the experiment with ſucceſs; uſing martial vitriol calcined to whiteneſs, inſtead of mangancſe. The whole paper is highly deſerving the attention of chemiſts.

In the fourth Chapter of the firſt Book of this Work I had obſerved in a note, that very complete ſets of ſmall apparatus for experiments with the blow-pipe, and with ſmall retorts and receivers, were ſold in London, under the inſpection of Mr. Magellan, by Brown, Bookſeller, Eſſex-ſtreet, in the Strand. The death of that worthy and active philoſopher induced me to cancel the note in the preſent Edition; but as Mr. Brown has ſince acquainted me that he has a conſiderable number of ſets remaining, I think I ſhall do a ſervice to the chemical ſtudent by repeating the information in this place.

BOOK I.

GENERAL CHEMISTRY.

CHAP. I.

GENERAL OBSERVATIONS ON CHEMISTRY, AND THE MEANS BY WHICH ITS OPERATIONS ARE PERFORMED

GENERAL OBSERVAT.

Chemiſtry defined.

CHEMISTRY may be conſidered either as a ſcience or an art. As a ſcience, its object is to eſtimate and account for the changes produced in bodies by motions of their parts which are too minute to affect the ſenſes individually. As an art, it conſiſts in the application of bodies to each other, in ſuch ſituations as are beſt calculated to produce thoſe changes.

Analyſis.

Syntheſis.

The operations of chemiſtry are either analytical, when compounded bodies are reſolved into their ſimpler parts; or ſynthetical, when ſimple bodies are united ſo as to form a compound. The former operation is called decompoſition; and the latter compoſition, or combination. There are few, and perhaps no chemical proceſſes, in which one of theſe effects takes place without the other.

Heat expands ſolids, then renders them fluid, and afterwards converts them into vapour, and theſe

GENERAL OBSERVAT. Heat.

changes ſucceed each other as the intenſity of the heat is rendered greater. There are many bodies not ſuſceptible of all theſe changes: but it is highly probable that this is owing to our want of power to produce a ſufficient degree of heat or coldneſs, and not to the peculiar nature of the bodies themſelves.

Analyſis by heat.

The heat required to render different bodies fluid or elaſtic, being different, affords a method of ſeparating the parts of compound bodies. If one part of a compound body be rendered fluid, while the others remain ſolid, the former will flow into the lower part of the containing veſſel, and leave the pores of the latter empty: or if one part be converted into vapour, it will riſe and fly off, leaving the other parts, whether ſolid or fluid, in the veſſel. Thus when a mixture of lead and copper is expoſed to a gradual heat, the lead melts firſt, and leaves the copper. And if a mixture of water and ſalt be heated, the water being converted into vapour, flies off, and leaves the ſalt behind.

Attraction.

All the parts of bodies attract each other. It is not neceſſary in this place to enquire, whether that attraction which cauſes bodies to gravitate or have weight, and by the energy of which the great motions of the planetary ſyſtems are governed, be the ſame as the attraction which cauſes their parts to adhere, and gives them firmneſs or ſolidity. It is enough that obſervation has not yet eſtabliſhed the truth of this propoſition; and, conſequently, it will be proper to conſider the attraction that is perceived to obtain in chemical operations, as a diſtinct property of matter.

The attractions which are obſerved in chemiſtry, are not found to have efficacy at any ſenſible diſtance between the parts; but doubtleſs, like the attractions of gravity, magnetiſm, and electricity, they are ſtronger the leſs the diſtance. The rigidity and permanent forms of ſolid bodies prevent many of the parts of two ſeveral bodies from coming near each other: for which reaſon, very little change is in general produced by their mutual action, even in the moſt favourable caſe, when powders are mixed together. But when one or both of the bodies is heated ſo as to become fluid, the particles eaſily move among each other, and can more readily obey the attractions which exiſt between them. Hence it has been conſidered as a chemical axiom, that bodies do not act on each other, unleſs one of them be fluid.—This aſſertion is liable however to the exception, that ſolid bodies will combine at a temperature too low to render either of them fluid, provided it be high enough to fuſe the compound they form. Thus ice and ſalt will combine at a much lower temperature than would liquefy either alone, if the temperature be not ſo low as to freeze the brine they form by uniting.

Chemical attractions

—act by means of heat

The whole art of the chemiſt therefore conſiſts, either in ſeparating the parts of bodies by the application of heat, or in placing them ſo that the order of arrangement of their parts may be changed by virtue of their ſeveral attractions, aſſiſted by heat ſufficient to fuſe one or more of them, or at leaſt ſufficient to produce fuſion in the compound.

Art of the chemiſt.

Since the order of arrangement of the parts of bodies is changed, when the chemical attractions are permitted to act, by a due ſituation of bodies with reſpect to each other; it clearly follows, that the attraction between ſome kinds of bodies is ſtronger than between others.

Elective attractions.

GENERAL OBSERVAT.

others. This difference was formerly ſuppoſed to proceed from a ſimilitude between the attracting bodies, and for that reaſon the attraction has been called the chemical affinity of bodies. But the term elective attraction is at preſent more generally uſed to denote this property.

Dry and humid way.

Though the operations with bodies that require a very ſtrong heat to render them fluid, do not eſſentially differ from thoſe which are made with ſuch bodies as are fluid at the uſual temperature of the atmoſphere; yet, as the apparatus for producing and maintaining the heat in the former caſe is unneceſſary in the latter, it is found convenient to diſtinguiſh the two methods by different appellations. Operations made with bodies habitually ſolid, which of courſe require to be acted on by a ſtrong heat, are ſaid to be made in the dry way; but operations wherein any ſubſtance is employed which is habitually fluid, are ſaid to be made in the liquid, humid, or moiſt way. No diſtinctive appellation has yet been generally adopted for operations made with elaſtic fluids; though ſome call this the pneumatic method.

Terms of art.

In every ſcience or art there are many things which require to be frequently mentioned. If theſe were deſcribed as often as they are mentioned, it is obvious that a great loſs of time would follow; and no advantage would be gained in perſpicuity, becauſe theſe deſcriptions would continually divert the mind from the leading object. For this reaſon it is abſolutely neceſſary to expreſs ſuch things by ſingle words or terms, which, when once underſtood, may always afterwards be uſed in the ſame ſenſe. Theſe will be explained in following treatiſe as they occur.

CHAP.

CHAP. II.

ON HEAT.

HEAT.
Of the word heat.

THE ſenſations expreſſed in common language by the words heat and coldneſs, are of too ſimple a nature either to require or to admit of definition. Theſe words, however, are not always uſed to denote the ſame things; but are indiſcriminately applied both to the ſenſation itſelf, and to that which cauſes it. Thus we ſay that we ourſelves are hot or cold, and that the fire or ice which heats or cools us is likewiſe hot or cold, though the ſenſations we experience are certainly very different things from that which enables bodies to excite them. It may alſo be remarked that, in this ambiguous manner of ſpeaking, there is another cauſe of uncertainty, that ariſes from the uſe of a variable ſtandard of compariſon. Every one knows that the eſtimate of heat or coldneſs differs in various perſons, becauſe each forms his judgment from his own ſenſations: and the ſame body may appear hot to one perſon, and cold to another, or to the ſame perſon at different times; though the variation is not in the body itſelf, but in the ſtate of the perſons in whom thoſe ſenſations are excited. Hence it appears neceſſary, in order to avoid error in the purſuit of enquiries concerning heat, that the ſenſe of the words made uſe of ſhould be accurately defined; and that ſome fixed ſtandard of compariſon be referred to inſtead of the human body, which, though fixed enough for the common affairs of life, is certainly not enough ſo for the purpoſes of ſcience.

Word heat.

The word heat, in a philoſophical ſenſe, is uſed to denote the cauſe of the power which bodies poſſeſs of exciting the ſenſations of heat or coldneſs.

Temperature.

The word temperature denotes the ſtate of the body with reſpect to that power. So that a body which excites a more intenſe ſenſation of heat or coldneſs than another body, is ſaid to poſſeſs a higher or lower temperature.

Cauſe of temperature.

It has not yet been determined in what heat itſelf, or the cauſe of temperature, conſiſts. Two opinions have long divided the ſcientific world. One is, that heat conſiſts of a peculiar motion or vibration of the parts of bodies, ſo that the temperature is higher the ſtronger the vibration: the other is, that heat is a ſubſtance or fluid, whoſe greater or leſs quantity produces a higher or lower temperature. Though the deciſion of this great queſtion is highly deſerving of the attention of philoſophers, yet it will not be neceſſary to conſider its merits in this place; and that more eſpecially, as the doubts reſpecting it will not impede our reaſoning concerning ſuch phenomena as are well known. For ſince effects are proportioned to their adequate cauſes, we may ſpeak of the quantities of heat in bodies, without deciding whether they be quantities of motion or quantities of matter; the relations of thoſe quantities to each other, and not their peculiar nature, being the chief object of our reſearch.

Common temperature.

Two bodies which, when in contact, neither impart nor receive heat from each other, are of the ſame temperature.

perature. All bodies, therefore, which by direct or ſucceſſive contact communicate with each other, muſt either have the ſame temperature, or the hotter will communicate heat to the others, till a common temperature is produced amongſt them.

Conductors of heat.

The diſpoſition or power of quickly tranſmitting heat in the production of a common temperature, is not the ſame in different bodies. If a number of ſtraight wires of equal ſizes, but different metals, be covered each with a thin coat of wax, and their ends be all plunged in the ſame heated fluid—for example, melted lead—the fuſion of the coat of wax will ſhew that heat is more quickly tranſmitted through ſome metals than others. Thus alſo it is found, that the end of a glaſs rod may be kept red-hot for a very long time, without any inconvenience to the hand which holds the other end; though a ſimilar metallic rod, heated in the ſame manner, would very ſoon become too hot to be held. Bodies that quickly alter their temperature by communication, are ſaid to be better conductors of heat than ſuch as alter more ſlowly.

Solid, fluid, and vaporous ſtates.

The general effects of a change of temperature are theſe:—A ſolid is rendered fluid by an increaſe of temperature, and a ſtill greater increaſe converts it into elaſtic fluid or vapour. If the body be compoſed of parts which become ſolid, fluid, or vaporous, at different temperatures; and the elective attraction by which thoſe parts are held together be inſufficient to prevent their aſſuming thoſe ſtates by the change of temperature, a ſeparation will then take place: thus a diminiſhed temperature ſeparates many ſalts from water, by their becoming ſolid; and an increaſed temperature ſe-

HEAT.

Expanſion by heat.

parates water from ſalts, by cauſing the former to fly off in vapour. Laſtly, if neither the change of temperature be conſiderable enough to alter the ſtate of ſolidity, fluidity, or vapour, which the body under conſideration may happen to poſſeſs; nor the body itſelf be of that nature as to undergo a ſeparation of its parts by the change; then an increaſe of temperature will cauſe an increaſe in the bulk or dimenſions of the body, which will laſt no longer than during the time of the increaſe.

Changes by heat do not follow the denſity, &c. of bodies.

It has already been obſerved, that the temperature at which different bodies change their form, is various. Neither this property, nor the expanſions of bodies by heat, have been obſerved to have any correſpondence with their denſity, hardneſs, ſpecific gravity, or other evident properties. There are likewiſe ſome irregularities in the contraction or expanſion, which depend on circumſtances not yet well aſcertained, near the freezing point of water, and probably other ſubſtances. Pure water, when cooled, is obſerved to contract till within about 8 degrees of the freezing temperature, where it begins to expand; and it may be cooled 11° below that temperature, and ſtill continue fluid. An adequate explanation of the circumſtances that attend the converſion of bodies from their ſeveral ſtates, of ſolidity, fluidity, and vapour, ſeems to promiſe a more intimate acquaintance with the nature and properties of the particles of bodies than has hitherto been obtained.

Irregularities.

Elaſtic fluids.

Permanently elaſtic fluids, or airs, appear to differ from vapour in the circumſtance that they take and retain the elaſtic form at a lower temperature. There are facts which render it probable, from analogy, that a great degree of cold would convert them into denſe fluids.

Quantity of heat in equal bodies:

It is a ſelf-evident truth, that if two bodies be perfectly equal and alike in all reſpects, and have the ſame temperature, they will poſſeſs equal quantities of heat. Thus, a pound of gold will poſſeſs an equal quantity of heat with another pound of gold, at the ſame temperature; a pound of water will poſſeſs an equal quantity of heat with another pound of water, at the ſame temperature; and ſo forth. From this it will alſo be clear, that two pounds of gold will poſſeſs twice as much heat as one pound of gold, at the ſame temperature; and, generally, that the quantities of heat in bodies of the ſame kind, and at the ſame temperature, will be in proportion to their quantities of matter or their weights.

—differing in temperature

If two ſuch equal and ſimilar bodies, that differ in temperature, be brought together, they will by communication acquire a common temperature, and their quantities of heat will by that means be rendered equal. For this purpoſe it is clear that the hotter of the two bodies muſt have communicated half its exceſs to the colder: the quantity of heat in one of theſe two equal bodies will therefore be an arithmetical mean between the two quantities originally poſſeſſed by each of them; that is to ſay, its temperature, or the common temperature, will exceed that of the colder exactly as much as it falls ſhort of that of the hotter body.

—in unequal bodies.

If the two bodies had been unequal, they would nevertheleſs have acquired a common temperature by communication, but the exceſs of heat would not have been equally divided between them; for we have ſhewn that the quantities of heat in ſuch bodies, at the ſame temperature, are in proportion to the quantities of matter. If the ſurplus of heat had been entirely taken away, it is obvious that their temperatures would have been made equal, and their heats would have been in that proportion; and there is no other way of adding the ſurplus to them, ſo as to preſerve the ſame proportion, but by giving more to the larger than to the ſmaller body, according to its quantity. The common temperature they acquire ſhews that this is done; and conſequently that, when two unequal bodies of the ſame kind acquire a common temperature by communication, the exceſs of heat in the hotter body is divided between them in proportion to their weights or quantities of matter.

Quantities of heat required to change temperature.

From this it is likewiſe evident, that the quantities of heat required to be added to or taken from bodies of the ſame kind, to produce equal changes in their temperature, will be in proportion to their quantities of matter.

Thermometer;

The foregoing deductions naturally lead us to the conſideration of an inſtrument proper to ſhew the temperatures of bodies. Such an inſtrument will require to be placed in contact with the body under examination, in order that it may acquire the ſame temperature. It is therefore an indiſpenſable condition, that the inſtrument ſhould be of that ſmall bulk as not ſenſibly to heat or cool the body it touches; but that the common temperature of the inſtrument, and the body itſelf upon contact, may, without perceptible error, be taken for the original temperature of the body.

—its requiſites.

body. Another condition equally requiſite is, that every change of temperature ſhall be attended with ſome evident change in the inſtrument by which it may be aſcertained. The expanſions and contractions of bodies are the moſt convenient for this purpoſe. Theſe, however, are ſmall; and would require to be magnified by ſome mechanical or optical contrivance, if a ſolid body were made uſe of. But the ſmalleſt change in the bulks of fluids may be eaſily ſhewn by the happy expedient of including them in a bottle whoſe neck is long, and very narrow, in proportion to the diameter of its body. On theſe conſiderations the thermometer is made. It conſiſts of a glaſs ball or bottle, with a long narrow tube or neck, and is partly filled with mercury; a fluid preferable to all others, from its unchangeableneſs, the regularity of its expanſions, and its not ſoiling the tube. The expanſions or contractions of the mercury are ſhewn by the riſe or fall of its ſurface, which is meaſured by a graduated ſcale uſually fixed to the tube.

Mercurial thermometer.

Correſpondence of the expanſions of mercury with the increments of heat aſcertained by De Luc;

The determination of the correſpondence between the degrees of the thermometer, and the actual variations of the heat of fluids, was firſt accurately determined by Mr. De Luc. By mixing equal quantities of water at different temperatures, he found that the thermometer very nearly indicated the arithmetical mean between the two temperatures, and conſequently that its indications are ſuch as truly correſpond with the quantities of heat.

—By Crawford.

As theſe fundamental experiments cannot be too ſtrictly examined, the following doubt remained to be conſidered, namely, whether the diſpoſition to give out or to receive heat, were the ſame in water at all temperatures; becauſe it is clear that, if this diſpoſition be changed by heating or cooling, the temperature, or power to heat or cool other bodies, will not follow the ſame proportion as the quantities of heat; though it may be imagined, not without probability in this caſe, that correſpondent irregularities in the expanſions of the mercury, may cauſe the thermometer to indicate the arithmetical mean between the two expanſions produced by any extreme temperatures. But whatever irregularities may be ſuppoſed to counteract each other in theſe experiments with mercury and water, it is to the laſt degree improbable that the ſame compenſation would be found, when the mean temperature is obtained by other methods. With this view the celebrated Dr. Crawford * very carefully repeated and confirmed Mr. De Luc's experiments; made others with a like reſult, by uſing linſeed oil inſtead of water, and alſo by producing the mean temperature, permanently, in air included in a cylinder formed of two equal parts, the upper of which was kept to the freezing point, by ſurrounding it with pounded ice; and the lower to the boiling-water point, by ſurrounding it with a greater ſupply of ſteam than could be condenſed by its contact. The near correſpondence of theſe ſeveral methods ſhews that the expanſions of the mercury in the thermometer are correſpondent with the heat it receives

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* On Heat. London, 1788. This moſt valuable performance contains the theory, and moſt of the facts, relating to heat; and deſerves to be made a part of the library of every natural philoſopher.

Quantities of heat in bodies of different kinds: —relative.

Thus far we have attended only to the communication of heat between bodies of the ſame kind; but when two equal bodies of different kinds produce a common temperature by communication, it ſeldom happens that it proves to be an arithmetical mean between the two original temperatures. In ſuch caſes it is evident that the heat which was communicated from one to the other, has not altered their temperatures equally, but has raiſed or lowered that of the one more than it has lowered or raiſed that of the other. And as the proportion between the number of degrees through which one of two bodies is thus raiſed, and the other lowered, is found by experiment to be the ſame, however different the two original temperatures may have been, provided no change of form or chemical combination has been produced in either of them; it is a general conſequence, that the quantity of heat required to alter the temperature of one of the bodies a ſingle degree, or any other equal part, will be greater or leſs than would be required to produce the ſame change in the other body, in proportion as the changes produced by the communicated heat were leſs or greater.

—abſolute.

The whole heat in each body, when they have the ſame temperature, muſt conſiſt of the ſame number of degrees: the proportion between the whole heats of the bodies will therefore be the ſame as between the heats required to raiſe each of them a ſingle degree: that is to ſay, the comparative heats of bodies, at the ſame temperature, will be in the inverſe proportion of the number of degrees their temperature is altered by the ſame quantity of heat.

Example.

To illuſtrate this by an example in round numbers

HEAT.

Suppoſe a pint of mercury, at the temperature of 136°, be mixed with a pint of water at 50°, the mean temperature will be 76°. The water therefore has been heated 26°, and the mercury has been cooled 60°, by the loſs of the heat it imparted to the water. The abſolute heat in one degree of the mercury will conſequently be proportionally leſs than that of one degree of the water; becauſe the very ſame heat which has raiſed the water 26 degrees in temperature, would raiſe the mercury ſixty, if it could be returned again: and the whole heat contained in the mercury will be to that of the water in the ſame proportion of 26 to 60. But in the preſent experiment equal bulks were uſed; and mercury is about 13 times as heavy as water. An equal weight of mercury would contain only one-thirteenth part of the heat. Twenty-ſix, divided by 13, quotes 2: whence the comparative heats of mercury and water are in the proportion of about 2 to 60, or 1 to 30; that is to ſay, a pound of mercury, at the ſame temperature, contains no more than one-thirtieth part of the heat contained in a pound of water.

Comparative heat.

It may be obſerved that the term comparative heat is uſed to denote the proportion of the abſolute quantity of heat in one body to that of another equal maſs of matter at the ſame temperature, conſidered as a ſtandard. The ſtandard made uſe of is pure water, in a fluid ſtate. Some writers call this ſpecific heat. The diſpoſition, or property, by which bodies ſeverally require more or leſs heat to produce equal changes in their temperature, is called their capacity for heat. Theſe capacities are conſidered as the unknown cauſe of the differences in their comparative heats, to which they are conſequently proportional.

Capacity.

Capacities in various ſtates.

It is found, by experiment, that the capacity of the ſame body for heat is leaſt when ſolid, greater when fuſed or fluid, and greateſt of all when it becomes converted into vapour, or elaſtic fluid.

—changes by chemical actions.

Alſo, when bodies unite by virtue of chemical attraction, their capacities are ſeldom the ſame as the ſum of the capacities of the bodies, but almoſt always either greater or leſs.

Inferences.

As the experiments relating to the capacities of bodies cannot be here given at large, it will be proper to mention, by way of inference, ſome of the chief conſequences of this moſt luminous doctrine; firſt premiſing, however, that theſe inductions have all been verified by experiment*.

Ice and water.

The capacities of ice and fluid water are found to be as 9 to 10. Ice cannot therefore be converted into water, unleſs it be ſupplied with as much heat as is ſufficient to anſwer the difference of capacity. Thus, if equal quantities of ice and water, both at the temperature of 32°, or the freezing point, be expoſed in ſimilar veſſels, at the ſame diſtance from a fire, both will receive heat alike; and the ice will be melted into water at 32°, while the water in the other veſſel will have its temperature raiſed to 178°. Here it is obvious that the ſame heat which raiſed the water 146 degrees, was merely ſufficient to ſupply the increaſed capacity of the ice; for which reaſon this laſt had not its temperature raiſed at all. If the experiment be more accurately made, by mixing equal weights of water at 178°, and ice at 32°, the ſame conſequence will follow;

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* For which conſult Dr. Crawford's Treatiſe, already ſpoken of.

for the ice will be melted, and the common temperature will be 32°; becauſe the ice in melting receives no augmentation of temperature, but abſorbs the whole 146° of heat from the water, by virtue of its increaſed capacity when it becomes fluid.

Stationary temperature, or freezing point.

And ſo likewiſe, when water is frozen by the loſs of its heat, communicated to a cold atmoſphere, or other contiguous bodies, the proceſs of cooling goes on till ice begins to be formed: but, during the whole time of the converſion of the water into ice, the temperature remains ſtationary, becauſe the diminiſhed capacity of the ice cauſes it to give out heat, the continual evolution of which ſupplies the refrigerating bodies with as much as their energy of cooling might otherwiſe have taken to cauſe a diminution of the temperature. When the whole is frozen, this ſupply of extricated heat ceaſes; and therefore the cauſe that cooled the water at firſt, goes on in cooling the ice, until the common temperature is produced.

Natural zero of temperature.

In all experiments wherein the capacities of the ſame bodies are changed, and the difference between the quantities of heat in the ſame body in both ſtates, at one common temperature, is known in degrees of the thermometer, we may derive the advantage of finding the abſolute quantities of heat in degrees of the thermometer, or the number of degrees which any particular point or temperature is remote from the true zero, or point of abſolute privation of all heat. To illuſtrate this curious poſition, the experiments on ice and water, juſt related, may be made uſe of. The whole quantities of heat, in theſe two ſtates, are as 9 to 10. It is plain, therefore, that when water freezes, it muſt give out one-tenth of its whole heat; and this tenth part, by the experiment, is found to anſwer to 146° of Fahrenheit's thermometer. Conſequently its whole heat is ten times 146°, or 1460° of Fahrenheit's thermometer, when its temperature is 32° above Fahrenheit's zero. Whence the natural zero * is at—1428°.

Capacity of ſteam.

No direct experiment has yet been made to ſhew the capacity of ſteam with relation to water. An indirect experiment of Dr. Crawford makes it as $15\frac{1}{2}$ to 10 †. It is accordingly found that ſteam, in its condenſation into water, gives out as much heat as would raiſe an equal quantity of non-evaporable matter, of the ſame capacity as water, 914 degrees. This heat it muſt have taken up at its formation. Whenever water is heated, we may conſequently conſider the heat as diſpoſed of in two ways. One part raiſes the temperature of the fluid water, and the other part is employed in ſupplying the elaſtic vapour that flies off with the heat which its increaſed capacity requires at that temperature. The greater the quantity of ſteam is produced, the larger will be the proportion of the heat employed in this laſt way. Now, there is a difficulty attends the formation of elaſtic vapour, in proportion as its eſcape is rendered more difficult. If the water be heated in a cloſe veſſel, no ſteam will be formed; if the ſteam eſcape by a ſmall hole, there will be leſs formed than if the whole ſurface of the water were uncovered; and if the ſuperincumbent atmoſphere be removed, as in the vacuum of an air-pump, the production will be greateſt of all. As the heat of the

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* Crawford, p. 458.

† Ibid. page 270.

water goes on increaſing, the production of ſteam will likewiſe increaſe, until the quantity is ſo great as its augmented capacity to carry off the whole heat that is communicated. At this period the increaſe of temperature will therefore ceaſe, and the temperature will become ſtationary. This point is called the boiling-water point. It varies, however, a little, as the preſſure of the atmoſphere varies, being loweſt when that is leaſt; becauſe the maximum of ſteam is produced at a lower temperature when the obſtacle to its eſcape is leſs. It has been ſtated, and with ſome probability, that there might be no interval of fluidity between the ſolid and vaporous forms, if it were not for the preſſure of the atmoſphere.

Boiling-water point of temperature.

In this manner it is eaſy to account for the cold produced by evaporation: for the volatile ſubſtance, when it takes the vaporous form, abſorbs as much heat from the body from which it evaporated, as its increaſed capacity requires. Every one muſt be acquainted with the cold produced by wetting the hand with water or with ſpirits of wine or brandy. The freezing of water, by means of the evaporation of ether, is a very remarkable inſtance of this. Water is included in a thin glaſs tube, and the outſide of the tube is kept continually wetted with ether, by means of a bottle with a capillary tube in its neck, through which the ether is poured. The conſequence of the ſpeedy evaporation of this very volatile fluid is, that in a very ſhort time the included water is ſuddenly converted into ice, even before a fire, or in the midſt of ſummer.

Evaporation produces cold.

Freezing by evaporation.

The effect of freezing mixtures is another evident conſequence of this doctrine. When as much common

Freezing mixtures.

mon ſalt is added to water as it can diſſolve, the brine continues unfrozen till it is cooled as low as 6° below 0°, on Fahrenheit's ſcale. Suppoſe pounded ice, or ſnow, to be mixed with ſalt at any temperature above —6°, their union will produce the brine here mentioned; which, becauſe the heat is above its freezing point, will become fluid, though the ice and ſalt were ſolid before. This fluidity will be attended with an increaſe of capacity, and therefore the brine will be much colder than the ſnow and ſalt were. If the quantity of ſnow and ſalt be conſiderable, and there be no bodies at hand which can readily ſupply heat, the brine firſt produced will cool the ſnow and ſalt in its vicinity; and this, when lequefied, will cool the reſt of the ſnow and ſalt ſtill more effectually. When the temperature of the whole is as low as—6°, or the freezing point of the brine, the liquefaction and cooling will ſtop, or it will proceed more ſlowly or faſter, in proportion as the requiſite heat is ſupplied. It may eaſily be imagined that, if a mixture of this kind be placed in a veſſel, and a ſmaller veſſel, containing water, be plunged in it, the cooling proceſs will freeze the water. It is likewiſe evident that ſuch mixtures will deſcend to a fixed temperature, which is that of their own freezing point*.

Fixed temperature of freezing mixtures.

So likewiſe the freezing proceſſes by the ſolutions † of ſalts in water or acids, though they have not yet been ſo minutely examined, may be explained from the difference of capacity produced in the liquefaction of ſolid ſalts, or the water contained in them. One of

Freezing proceſſes by diſolving ſalts in water.

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* Crawford, p. 474.

† Walker, in Philoſ. Tranſ. Vol. LXXVII. and LXXVIII.

theſe

HEAT.

Mixture of ſalts for freezing water.

theſe may be here mentioned, not as the moſt powerful, but becauſe the materials are cheap, and well known. It conſiſts of equal parts of ſal-ammoniac and ſaltpetre, finely powdered. If four ounces of water be poured on three ounces of this mixture, the ſolution will ſink the thermometer 36 degrees; and as it is eaſy to have pump-water as cool as 50° in the midſt of ſummer, this addition will cool it to 14°, which is therefore ſufficient to freeze water in a phial plunged in it.

General view of the agency of heat.

Without entering more largely into examples of the conſequences of the change of capacity in bodies which are changed in their form, or ſtate of chemical combination, it may be obſerved, in general, that as the powers of gravity and projection, in continual oppoſition to each other, produce all the beautiful effects in the great ſyſtem of the univerſe to which they are eſſential; ſo, among the actions of the minute parts of bodies, the coheſive attraction, and the energy of heat, are in continual oppoſition to each other, and are concerned in every proceſs by which changes are produced in the peculiar properties of bodies: and for whatever more immediate purpoſes it may be that the Supreme Intelligence has thus generally appointed their agency, we ſee that the changes of capacities are greatly conducive to the preſervation of a more equal temperature than would otherwiſe be found in the diſtricts around us. The cold produced by evaporation greatly mitigates, and conducts to other parts, the ſtrong heats of the torrid zone; and the heat developed on the freezing of water prevents the cold from falling ſo far below the freezing point as otherwiſe it might do.

Advantages ariſing from the changes of capacities.

do. If the capacities of water and ice were equal, the freezing of immenſe bodies of water would ſcarcely be progreſſive, but would take place the inſtant the whole was cooled to 32°; and ſo likewiſe the thawing of vaſt tracts of ſnow and mountains of ice would be performed in the ſhort time of the tranſmiſſion of the heat required to raiſe its temperature the minuteſt portion of a degree above the temperature of ſolidity. Whether the extreme inconveniences the hotter climates would undergo from increaſed heat, or the colder from the intenſe freezing and ſudden thaws, be among the principal events in the view of the Sovereign Diſpoſer of the univerſe, cannot, from our ignorance of final cauſes on ſo large a ſcale, be determined.

Queſtion, page 6.

Whether heat be matter or motion, is a queſtion which, as was before obſerved, is not well ſettled. It is certain that the motion of friction, or percuſſion, either produces or collects heat; and if the ſuppoſition of the mere vibration of parts could adequately account for the effects, it would doubtleſs be more ſimple than to call in the aſſiſtance of a material ſubſtance endued with peculiar properties. But, on the other hand, the appearances are ſolved with great eaſe and ſimplicity by the ſuppoſition of ſuch a ſubſtance. On this ſubject it may perhaps be ſufficient to obſerve, that the phenomena of heat ſeem to ſtand ſingle, ſo as not eaſily to admit of compariſon with any of the other appearances in nature; and conſequently that all reaſoning by analogy promiſes very little elucidation of a ſubject which can only be proſecuted by experimental reſearch.

The philoſophy of heat admits no analogy.

HEAT.

Diminution of capacity increaſes weight.

Attempts have been made to determine whether the weight of bodies is affected by the greater or leſs quantity of heat they may contain. The moſt accurate experiments ſhew that the ſame water is heavier, by a very minute quantity, when it is converted into ice*.

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* Dr. George Fordyce made the experiment by weighing the ſame quantity of water (about 1700 grains), when frozen and when unfrozen, at the temperature of 32°, in a room where the air was of the ſame temperature. The ice was near one-ſixteenth of a grain heavier. Phil. Tranſ. Vol. LXXV. p. 362.—Sir Benjamin Thompſon obtained the ſame concluſion, by counterpoiſing water againſt ſpirit of wine, and expoſing the apparatus to a cold atmoſphere which froze the former.

CHAP.

CHAP. III.

THE CONSTRUCTION OF THE THERMOMETER.

THERMOMETER.

IN the preſent cultivated ſtate of philoſophical knowledge, it can hardly be ſuppoſed that the reader has not ſeen a thermometer. Minute deſcription is therefore unneceſſary. But as the accurate conſtruction and ſubſequent improvement of this inſtrument muſt greatly depend on the knowledge, which thoſe who uſe it may poſſeſs, of the method of making it; and as we have no perfect account of this, there can be no doubt but a ſhort relation of the whole proceſs, from experimental knowledge, will be acceptable.

Conſtruction of the thermometer.

The tubes may be had at the glaſs-houſe; and the firſt care of the artiſt muſt conſiſt in examining if their cavities be equal or cylindrical throughout. This is done by immerſing one end into mercury, and withdrawing it, after cloſing the other end with the finger. By this means a ſmall quantity of mercury will enter the tube, which will occupy a longer ſpace the deeper the tube is immerſed. Lay the tube horizontally upon a graduated rule, and obſerve the length of the mercurial column, in different parts of the tube to which it may be made to run, by inclining it more or leſs. If the length continues invariably the ſame, it is a proof that the tube is uniformly cylindrical; but, if otherwiſe, the diameter varies, and the tube cannot be uſed to make a good thermometer, unleſs the graduations in the dif-

To determine the cylindrical form of the bore.

ferent parts of the tube be lengthened or ſhortened, in proportion to the meaſures of the mercurial column.

Method of blowing thermometers.

Direct the flame of a large candle, a watch-maker's lamp, or, which is cleanlieſt and beſt of all, a lamp with ſpirits of wine, upon one end of the glaſs tube, by means of the blow-pipe. The extremity will ſoon become red hot, and in a ſtate of imperfect fuſion. Remove the tube from the flame, and blow into its other end, and the heated part will be inflated ſo as to form a bulb. This laſt inflation is the moſt difficult and laborious part of the buſineſs; but it may be performed with great eaſe and advantage, by previouſly faſtening the neck of one of the ſmall bottles of elaſtic gum, or India rubber, about the end of the tube; which, when the other end is ignited, may be preſſed by the hand, ſo as to blow the bulb very commodiouſly, and without the introduction of any moiſt air.

Filling with mercury.

Immerſe the open end of the thermometer tube into ſome very clean dry mercury that has been boiled, and warm the bulb with a candle; part of the air will be immediately heard ruſhing through the mercury; withdraw the candle, and, as the bulb cools, the mercury will riſe in the tube. This will be facilitated by holding the tube as near an horizontal poſition as can be done, without raiſing its lower end above the ſurface of the mercury. In this way the bulb will be nearly half filled. Without altering the poſition of the apparatus, move the whole ſo that the bulb may be held over a candle. A ſmall candle newly ſnuffed is beſt, becauſe of the ſteadineſs of its flame; and it will be neceſſary to wrap a piece of paper round the tube, to defend

THERMOMETER.

defend the finger and thumb from its heat. The mercury will ſoon boil, and moſt of the remaining air will be heard eſcaping from the bulb. As ſoon as this eſcape has ceaſed, remove the bulb from the candle, and it will be ſuddenly filled with mercury from the veſſel.

Boiling the mercury in the tube.

Take the thermometer thus filled out of the mercury, and wrap round its open end a piece of thin paper, in ſuch a manner as to leave a cavity beyond the tube, at leaſt ſufficient to hold as much mercury as the bulb contains; ſecure this by wrapping it tight with packthread about the tube; then put a drop of mercury into the paper cavity, and apply the bulb again over the ſnuffed candle, holding the tube upright between the finger and thumb, or a pair of ſmall pincers, at the part wrapped with paper and packthread: the mercury will ſoon boil, and about half the contents of the bulb will ruſh violently up the tube into the paper. Remove the bulb from the candle, and the mercury will ſuddenly return: then boil it again; and repeat the operation till the ſpeedy boiling of the mercury, when placed over the candle, and the diminiſhed noiſe and agitation, ſhew that the whole has been well heated, and deprived of the air or moiſture which might have adhered to it.

Caution.

The operation of boiling will fail, if the mercury, or the inſide of the bulb, be moiſt; for in this caſe the bulb is uſually burſt by the mercurial vapour; the exploſion however is not dangerous: it is very likely to happen with bulbs blown by the mouth, unleſs they be kept ſome weeks in a dry place, before they are filled. The ſame danger makes it prudent not to boil the mercury ſtrongly the firſt or ſecond time; and it is likewiſe of importance to keep the bulb clear of the flame, as the contact of this laſt againſt the empty part of the bulb would melt it, and a hole would be immediately made by the excluded vapour.

Trial of the proportion between the bulb and the tube.

After the boiling is completed, plunge the bulb into cold water, whoſe temperature is known. Melting ice or ſnow (or ſnow and water) always has the temperature of 32° of Fahrenheit's ſcale. Then take off the paper, and put the bulb into the hand, and afterwards into the mouth; this heating will cauſe ſome of the mercury to drop out of the tube. Cool it again to 32°, by immerſing it in the cold water, and mark where the mercury ſtands. The diſtance between this ſtation and the top of the tube meaſures the interval between freezing and blood heat, or 32 and 95, which makes 63 degrees; and will conſequently ſhew whether the degrees will be large or ſmall, and what extent the ſcale is capable of; that is to ſay, it will ſhew whether the bulb is of the proper ſize. This laſt, ſuppoſing the judgment of the operator not ſufficient to proportion the bulb nearly to the tube, and the intended ſcale, might however have been more conveniently aſcertained after the firſt filling, before the boiling had been undertaken.

Hermetical ſealing of the tube.

When the number of degrees to which the length of the tube will extend is thus known, the operator muſt ſettle whereabouts he will have the freezing point, which may be nearer or farther from the bulb, accordingly as he intends the inſtrument to be uſed, more particularly to aſcertain great degrees of heat, or

THERMOMETER.

or of cold. At this ſtage of the buſineſs, likewiſe, he may heat the upper part of the tube with the blow-pipe, and draw it out to a fine capillary tube ready for ſealing. The bulb muſt then be heated in the candle, till a few particles of mercury have fallen off the top of the tube; and notice muſt then be taken how much nearer the freezing point is to the bulb than before, which may be done by immerſing it in the melting ſnow, as before. If it be not as low as deſired, the heating muſt be repeated, carefully obſerving not to throw out too much mercury at a time. When the due quantity of mercury is thus adjuſted, two candles muſt be prepared, the one to heat the bulb, and the other to cloſe the tube. The blow-pipe being in readineſs, the upper part of the tube near the flame of one candle, and the bulb near the flame of the other, the mercury will riſe, and at laſt begin to form a globule at the point of the capillary tube. At this inſtant the bulb muſt be withdrawn from the lower candle, at the ſame time that the flame of the upper is directed by the blow-pipe upon the point of the tube. This laſt will be immediately ignited, and will cloſe by the melting of its parts, before the mercury has perceptibly ſubſided. When the mercury has fallen, this cloſure may be rendered more ſecure from accidental breaking, by fuſing the whole point of the tube, till it becomes round.

Proof of internal vacuum.

If this buſineſs be properly done, the mercury in the inſtrument thus filled will run backwards and forwards in the tube, immediately upon inverting its ſituation.

Adjuſtment of the fixed points.

In the original graduation of thermometers, two fixed points of temperature are neceſſary. Theſe are the freezing point of water, or temperature of ice or ſnow, at the inſtant of formation, or rather when it is juſt beginning to liquefy; and the boiling point of water, or temperature at which, under a known preſſure, it is plentifully converted into ſteam. For the ſettling the freezing point, nothing more is neceſſary than to immerſe the thermometer ſo deep in melting ſnow or ice, as that the mercury may be barely viſible above its ſurface, and carefully mark the place at which it ſtands.

Freezing.

The boiling point is not quite ſo eaſily aſcertained; crude, hard, or ſaline waters acquire a greater heat in boiling than ſuch as are purer; and the ſame water will acquire a greater heat under a greater preſſure. For this laſt reaſon, the boiling point ſhould be fixed according to the deciſion of the committee of the Royal Society; namely, when the barometer ſtands at 29.8 inches. The beſt method is to provide a veſſel ſomewhat longer than the thermometer, with a cover, and two holes in it; one about an inch in diameter, for the ſteam to eſcape; and the other ſmaller, for the thermometer tube to be faſtened in it. When this is uſed, the thermometer muſt be faſtened in the cover, ſo that the eſtimated place of the boiling point may be juſt above the hole. Water muſt be put in the veſſel, not ſufficient to touch the bulb of the thermometer, when the cover ſhall be put on. The veſſel muſt then be covered, a thin plate of metal laid on the ſteam hole, and the water made to boil by heat applied to the bottom only. The thermometer will be then ſurrounded with ſteam, which will raiſe its temperature

Boiling.

perature to the boiling point; and this point muſt be carefully marked on the tube. The following method may be more convenient to thoſe who are not provided with ſuch a veſſel:—Wrap ſeveral folds of linen rags or flannel round the tube, nearly as high as the ſuppoſed boiling point; hold the ball of the thermometer in the aſcending current of boiling rain-water, about two or three inches below the ſurface; pour boiling water on the rags three or four times, waiting a few ſeconds between each time; and wait ſome ſeconds after the laſt time of pouring on water, in order that the water may recover its full ſtrength of boiling, which is conſiderably checked by the pouring on the rags. The place where the mercury ſtands is the boiling-water point.

Adjuſtment for errors of the tube.

Notwithſtanding the accurate adjuſtment of the fixed points of a thermometer, yet if the tube be not truly cylindrical, or if the diviſions be not adjuſted to the inequalities of its diameter, the errors at the middle, between the two fixed points, may amount to more than a whole degree. A ſmall error in the ſtanding of thermometers may be occaſioned by the varying preſſure of the atmoſphere, which alters the capacity of the glaſs; but it never amounts to ſo much as the tenth part of a degree. Spherical bulbs are leaſt ſubject to this.

Standard thermometer.

Thermometers which, from the great length of their degrees, or for any other reaſon, are made to take in but a ſmall part of the interval between the two fixed points, are uſually graduated by compariſon with a ſtandard thermometer.

The

THERMOMETER.

Caſes in which the mercury need not be boiled.

The very careful boiling of the mercury, as above deſcribed, is abſolutely neceſſary for ſuch thermometers as are to be ſealed when full: for if there were any air or moiſture left in the bulb, it would prevent the mercury in the tube from deſcending into the bulb, ſo that the tube would continue always full. Theſe thermometers are undoubtedly the beſt; but the vacuum above the mercury does not ſeem to be an indiſpenſable requiſite. If a clean dry tube be filled with pure boiled mercury, and a ſmall bulb be left at the top of the tube, to contain common air, in order that its expanſion or condenſation, produced by the change in the mercurial ſurface, may be inconſiderable; there will be few practical objections againſt ſuch a thermometer; more eſpecially if it be a ſecondary inſtrument, graduated by means of a ſtandard. There are ſome thermometers made with tubes ſo very ſmall, and bulbs ſo large in proportion to them, that they will not admit of boiling the mercury in them, but are filled with boiled mercury by means of a condenſer. Theſe are neceſſarily of the kind here mentioned.

Scales of thermometers. Fahrenheit's.

The thermometers moſt in uſe at preſent are Fahrenheit's, Reaumur's, and Celſius's. In Fahrenheit's ſcale the number of degrees between the freezing and boiling water point is 180; the freezing point being at 32°, and the boiling point at 212°, both above 0°, or the part from which the degrees are reckoned both ways.

Reaumur's.

In Reaumur's ſcale the number of degrees between theſe two points is 80, and the freezing point is called 0°, from which the degrees are reckoned both ways.

Celſius's.

In Celſius's thermometer, the interval is divided into 100°, and the freezing point is called 0°, as in Reaumur's. To reduce theſe ſcales to each other, it muſt be obſerved, that one degree of Fahrenheit's is equal to $\frac{4}{9}$ of a degree of Reaumur, and to $\frac{5}{9}$ of a degree of Celſius. Therefore, if the number of degrees of Fahrenheit, reckoned above or below the freezing point, be multiplied by 4, and divided by 9, the quotient will be the correſponding number on Reaumur's ſcale. Or if the multiplier 5, and the diviſor 9, be uſed, the quotient will give the degrees of Celſius's ſcale. And, contrariwiſe, if any number of degrees, either of Reaumur or Celſius, be multiplied by 9, and divided by 4 if of Reaumur, or by 5 if of Celſius, the quotient will give the degrees of Fahrenheit, reckoned either above or below the freezing point, as the caſe may be.

Reduction of degrees of thermometers of various ſcales.

CHAP. IV.

ON COMBUSTION, AND THE APPLICATION OF HEAT TO CHEMICAL PURPOSES.

APPLICAT. OF HEAT.

Friction; hammering; flint and ſteel.

Solar focus.

Chemical mixtures.

THE methods of producing an increaſe of temperature are various. The friction of two pieces of wood, in a turner's lathe, produces heat and flame; a nail may be made red-hot by hammering it: and when flint and ſteel are ſtruck together, ſmall particles of the ſteel are ſeparated, which are in a ſtrong ſtate of deflagration, and, upon examination with the microſcope, are found to have been fuſed into hollow greyiſh balls. The ſun's light, concentrated by a convex lens, or concave mirror, is likewiſe found to produce the moſt aſtoniſhing effects, by raiſing the temperature of bodies. And, among chemical mixtures, there are many by which ignition and flame are produced. In theſe, and in all inſtances where the temperature is raiſed, a diminution of the capacities of the bodies appears to be the effective cauſe.

Combuſtion.

Moſt operations that require an increaſe of temperature, are performed by the communication of heat from bodies in combuſtion. The general facts reſpecting this wonderful proceſs, are the following:— There are certain bodies which, when ignited or heated ſo as to become luminous, will ſoon ceaſe to be ſo, by the loſs of that heat which they communicate to the bodies around them: but there are others which, Combuſtion.

which, if ignited in contact with the air of the atmoſphere, will not loſe their ignition, but continue to give out heat, till their volatile parts are diſſipated, and the properties of the remainder entirely changed. Theſe laſt are called combuſtible bodies. It is found by experiment that the capacities or quantities of heat, in combuſtible bodies, are not conſiderable; that the quantity of heat in atmoſpheric air, in the elaſtic ſtate, is exceedingly great; and that part of this air is abſorbed by bodies in combuſtion. If, therefore, the temperature of a combuſtible body be by any means ſo raiſed, as that the chemical proceſs, by which air becomes condenſed and combined with it, may go on, the temperature of the air will be raiſed, as its capacity is diminiſhed, in paſſing from the elaſtic to the ſolid ſtate; and it will therefore give out its heat to the combuſtible body, which, inſtead of becoming colder, muſt increaſe in temperature, in proportion to the quantity of air condenſed in the ſame time, excepting ſo far as this effect is diminiſhed by the conducting power of the ſurrounding bodies.

Proceſſes.

The proceſſes which are performed by the ſimple application of heat, are as follow:

Roaſting.

Roaſting.—This conſiſts in expoſing mineral bodies to the heat of an open fire, for the purpoſe of diſſipating their volatile contents.

Calcination.

Calcination is performed by expoſing bodies, in an open veſſel, to a ſtrong heat, till no farther change can be produced in them. The body which remains, and withſtands the fire, is called a calx. Both theſe terms are more particularly applied to metals. Such bodies as are very little changed by heat, are called refractory.

Fuſion

APPLICAT. OF HEAT. Fuſion. Fuſion conſiſts in heating bodies, in proper veſſels, till they become fluid. It is chiefly uſed for the purpoſe of uniting ſmaller bodies into one large maſs, and caſting them into moulds of any deſired figure. The facility with which metals may be united in this way, after they have been divided, is probably the circumſtance that induced mankind to uſe them as the mediums of exchange, or ſigns of value of all other commodities.

Digeſtion. Digeſtion conſiſts in keeping bodies for a conſiderable time immerſed in a fluid at a higher temperature than that of the atmoſphere, in order that combinations may take place that could not elſe have been effected.

Cementation. Cementation is a proceſs wherein ſolid bodies, one or more of them being pulverized, are expoſed to heat in proper veſſels, with the intention that the more volatile parts of the one body may unite with the other, or with its fixed parts.

Evaporation. Evaporation conſiſts in the diſſipating of fluids by heat.

Concentration. Concentration conſiſts in increaſing the proportion of ſaline matter in any watery fluid, either by evaporating part of the water, or by cauſing it to freeze, and taking away the ice.

Diſtillation. When evaporation is performed in veſſels either perfectly or nearly cloſed, ſo that the volatile parts, which are raiſed in one part of the apparatus, may be received and condenſed in the other part, the proceſs is called diſtillation.

Rectification. Rectification is a ſubſequent diſtillation of the product which comes over.

Sublimation. In the diſtillation of ſuch bodies as are ſolid in the uſual temperature of the atmoſphere, the vapours are ſcarcely condenſed before they become ſolid. In this caſe the proceſs is called ſublimation; and the condenſed vapours, which uſually have a powdery form, are called flowers. Such are the flowers of brimſtone, of benjamin, of zinc, &c. Solid products, obtained in this way, are called ſublimates.

Flowers.

Sublimates.

Some of theſe operations may be performed by a common culinary fire; and indeed moſt of them may when the quantities of matter are ſmall, which is uſually the caſe in philoſophical experiments. In the arts, where every proceſs requires to be repeatedly carried on in the large way, a variety of furnaces have been contrived, to ſuit the various intentions of the operators. But experimental inquiries demand the occaſional exertion of every branch of chemical operation; for which reaſon, the furnaces and apparatus ought to be conſtructed on as general principles as poſſible.

Common fire.

The veſſels uſed in chemiſtry are—Fig. 1. Crucibles, or pots, made either of earth, black lead, forged iron, or platina. They are uſed for roaſting, calcination, and fuſion.

Crucibles. See the plate.

Fig. 2. Cucurbits, mattraſſes, or bodies, which are glaſs, earthen, or metallic veſſels, uſually of the ſhape of an egg, and open at top. They ſerve the purpoſes of digeſtion, evaporation, &c.

Cucurbits, or mattraſſes.

Fig. 3. Retorts are globular veſſels of earthen ware, glaſs, or metal, with a neck bended on one ſide. Some retorts have another neck or opening at their upper part, through which they may be charged, and the opening may be afterwards cloſed with a ſtopper. Theſe are called tubulated retorts.

Retorts.

APPLICAT. OF HEAT.

Receivers.

Fig. 4. Receivers are veſſels, uſually of glaſs, of a ſpherical form, with a ſtraight neck, into which the neck of the retort is uſually inſerted. When any proper ſubſtance is put into a retort, and heated, its volatile parts paſs over into the receiver, where they are condenſed.

Alembic — of glaſs;

Fig. 5. The alembic is uſed for diſtillation when the products are too volatile to admit of the uſe of the laſt-mentioned apparatus. The alembic conſiſts of a body A, to which is adapted a head B. The head is of a conical figure, and has its external circumference or baſe depreſſed lower than its neck; ſo that the vapours which riſe, and are condenſed againſt its ſides, run down into the circular channel formed by its depreſſed part, from whence they are conveyed by the noſe or beak C, into the receiver D. This inſtrument is leſs ſimple than the retort, which certainly may be uſed for the moſt volatile products, if care be taken to apply a gentle heat on ſuch occaſions. But the alembic has its conveniencies. In particular, the reſidues of diſtillations may be eaſily cleared out of the body A; and, in experiments of ſublimation, the head is very convenient to receive the dry products, while the more volatile and elaſtic parts paſs over into the receiver.

—of metal.

Fig. 6, Is the drawing of an alembic commonly made in metal. The head is contained in a veſſel of cold water, to accelerate the condenſation; a method which is not ſo rational as that of cooling the receiver, becauſe the coldneſs of the head, in the former caſe, cauſes much of the vapour to fall again into the body.

Stills for ardent ſpirits.

Fig. 7, Repreſents the large ſtills uſed in the diſtillation of ardent ſpirits. Inſtead of uſing a refrigeratory or receiver, the ſpirit is made to paſs through a ſpiral pipe, called the worm, which is immerſed in a tub of cold water. During its paſſage it is condenſed, and comes out at the lower extremity, E, of the pipe, in a fluid form.

Furnaces.

The beſt conſtruction of a furnace has not been well aſcertained from experience. There are facts which ſhew that a fire made on a grate near the bottom of a chimney, of equal width throughout, and open both above and below, will produce a more intenſe heat than any other furnace. What may be the limits for the height of the chimney, is not aſcertained from any preciſe trials; but thirty times its diameter would not probably be too high. It ſeems to be a diſadvantage to contract the diameter of a chimney, ſo as to make it ſmaller than that of the fire-place, when no other air is to go up the chimney than what has paſſed through the fire; and there is no proſpect of advantage to be derived from widening it.

Melting furnace.

Fig. 8, Exhibits the common ſmall furnace for melting. A is the aſh-hole, where the air enters. C is the fire-place, containing a covered crucible ſtanding on a ſupport of baked earth, which reſts on the grate. D is the paſſage into E the chimney. At D is a ſhallow crucible called a cupel, placed in the current of the flame; and at F is an earthen or ſtone cover, to be occaſionally taken off, for the purpoſe of ſupplying the fire with fuel.

Reverberatory furnace.

Fig. 9, Is the reverberatory furnace. A is the fire-place, B the dome and chimney, which is moveable. It ſerves to reflect the flames, and cauſes them to ſurround the veſſel c, which is by that means more ſtrongly heated than otherwiſe.

Fuel.

Charcoal is the material moſt commonly uſed in furnaces. It produces an intenſe heat, without ſmoke; but it is conſumed very faſt. Coke, or charred pit-coal, produces a very ſtrong and laſting heat. Neither of theſe produce a ſtrong heat at a diſtance from the fire. Where the action of flame is required, wood or coal muſt be burned. Several inconveniencies attend the uſe of coal, as its fuliginous fumes, and its aptitude to ſtop the paſſage of air, by becoming fuſed. It is uſed however in the reverberatory furnaces of glaſs-houſes; and is the beſt material where veſſels are to be ſupplied with a great quantity of heat at no great intenſity, ſuch as in diſtilleries, &c.

Chemical bath.

In many operations where a moderate and regular heat is required, it is advantageous to uſe a bath, or to coat the veſſel intended to be heated. A chemical bath is uſually made by putting a quantity of water, ſand, or other fluid or pulverulent ſubſtance, into a metallic veſſel or pot, and immerſing the diſtilling veſſel in it. When the water or ſand is once heated, it prevents the ſudden changes in the intenſity of the fire from affecting the veſſel that contains the matter under examination. Chemical baths are made with water, ſand, iron filings, mercury, and with the fuſible compoſition of eight parts biſmuth, five lead, and three tin, which becomes fluid with a leſs heat than that of boiling water.

Coating.

Coating is chiefly intended to prevent glaſs veſſels from cracking by the ſudden variations of heat; and ſerves likewiſe to render them capable of preſerving their figure in higher degrees of heat than they could ſuſtain without it. The materials are clay and fine ſand, well worked together into a paſte, and with the addition of ſome hair, ſuch as the bricklayers uſe. This is laid upon the veſſel in ſucceſſive thin coatings.

Lutes. The joints or cloſures of veſſels are made tight by compoſitions called lutes. The clay and ſand uſed for coating, make a very good lute. In the diſtillation of ſubſtances which are not corroſive, it is found convenient to cloſe the junctures with paper, or linen, paſted on. Wet ſtrips of bladder may alſo be uſed in theſe caſes. Slacked lime and the whites of eggs form a good lute, which ſpeedily dries and becomes firm; but the compoſition called fat lute is uſed when the vapours are of a corroſive and volatile nature. This is compoſed of clay, firſt made very dry and pulverized, and then beat together into a paſte with linſeed oil which has been boiled upon litharge, and is known in the ſhops by the name of drying oil. Fat lute does not harden, but requires to be ſecured on its place by ſtrips of linen dipped in the lute made of lime and whites of eggs.

Fat lute.

Lamp. The flame of a lamp with many ſmall wicks may be uſed in diſtillations that require a low heat.

Facility of making experiments. An ingenious ſtudent in chemiſtry, when he has familiarized himſelf with the firſt principles, will ſoon perceive that there are few philoſophical inquiries, if any, that require a large apparatus of furnace, or veſſels. A tobacco-pipe is a very uſeful crucible, in which a great number of operations may be performed in a common fire, eſpecially if urged with a pair of good double bellows. An earthen pot, or iron ladle, will contain a ſand-bath; and apothecaries phials, or Florence

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flaſks, ſerve very well for mattraſſes. Chafing-diſhes, or ſmall iron ſtoves, may be applied to ſerve many uſeful purpoſes. And the blow-pipe and ſpirit-lamp, with a ſet of very ſmall retorts and receivers, may be adapted to the performance of almoſt every part of experimental chemiſtry.

Moveable furnaces.

The black-lead pots are very convenient for conſtructing a variety of moveable furnaces. They may be cut without difficulty by a ſaw whoſe teeth are ſet wide; and very eaſily admit of being ſcraped, drilled, or ground with ſand, to give them the requiſite figure. In Dr. Lewis's conſtruction, from whom the four following figures are taken*, the pots which are intended to be applied to each other, are ground flat upon a ſtone, with a little ſand; the holes are ſawed with the common compaſs-ſaw of the carpenters, and are made a little narrower externally than internally; by which means it is eaſy to fit them with ſtoppers made out of the broken pieces, that may be bought where the pots are ſold. Three or four hoops of copper-wire, about the thickneſs of a crow quill, and firſt ſoftened by heating it red-hot, are faſtened round the pots in the moſt convenient places, to render them more durable by keeping their parts together, after they may have been craked. A thin copper hoop ſerves to ſecure the place of junction of two pots.

Furnace for open fire.

Fig. 10, Repreſents a furnace for open fire formed by one pot. The lower ſquare aperture is the door of the aſh-pit, and the upper one the door of the fire-place, which, in the intentions this furnace is deſigned for, is kept ſhut. The charcoal is put in at the top, and ſupplied with air by one or more of the lower apertures; and the intenſity of the fire may in ſome meaſure be regulated by more or leſs cloſing of the apertures. If an iron pot, a ladle, or an old frying-pan, containing ſand, be put over this fire on three iron ſupporters, ſo as to leave room for the eſcape of the burned air from the fire, a bath will be formed, in which digeſtions, diſtillations, and other chemical operations, may be performed. The round hole in the bottom ſerves to inſert the nozzle of a pair of bellows, which, when the other apertures are ſtopped, converts it into a blaſt furnace.

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* Lewis's Philoſophical Commerce of Arts.

Bath.

Fig. 11, Is a wind furnace, formed by two pots applied mouth to mouth. An iron chimney compoſed of pieces, by which its length may be regulated ſo as to increaſe the draft at pleaſure, is put on the top. The crucible containing the ſubject matters, is placed upon a circular piece of brick laid upon the grate, which prevents the cold air from immediately ſtriking the crucible, and endangering the breaking it. The charcoal is put through the fire-place door, or larger aperture of the dome, or upper pot, which ſhould always be cloſed immediately after each ſupply of fuel. The two oppoſite holes in the upper part of the dome afford the conveniency of paſſing an iron rod through, for ſafely and commodiouſly lifting it when intenſely heated.

Moveable wind furnace.

Fig. 12, Is a furnace conſiſting of two pots, ſeparated by an iron hoop, in which an opening or door is cut. It ſerves for a reverberatory furnace for diſtilling with retorts of earthen ware or coated glaſs. The

Reverberatory furnace.

bottom of the diſtilling veſſel reſts on two bars laid acroſs within the lower pot. If the grate of this furnace be occaſionally changed for a larger, which may be placed near the edge of the lower pot, a muffle, or ſmall earthen oven, may be placed in the midſt of the fire, with its mouth oppoſite the hole in the iron hoop. In this may be performed all proceſſes that require the admiſſion of air, and frequent inſpection, ſuch as aſſays, enamelling, &c.

Moveable blaſt furnace.

Fig. 13, Is an improved blaſt furnace. The pot which contains the fuel for this purpoſe, has a number of holes bored at ſmall diſtances, in ſpiral lines, all over it, from the bottom up to ſuch an height as it is deſigned the fuel ſhall reach. The crucible is placed upon a proper ſupport in the bottom; and the holes are made, not in a perpendicular direction to it, but oblique, that the ſtreams of air forced in through them may but juſt touch it: by this means the crucible is in no danger of being cracked by the blaſt, and the impelled heat plays in a kind of ſpiral upon its ſurface. The lower pot receives this perforated pot to ſuch a depth that all its holes hang in the cavity; which cavity having no other outlet than the aperture for the bellows, the air blown in through this aperture neceſſarily diſtributes itſelf through the perforations of the inner pot. Both pots may be of the largeſt ſize, the external narrow part of the inner falling into the wide mouth of the outer. It wants no addition to its height; but, on the contrary, will be more commodious in regard to the inſpection and taking out of the crucible, if all the part above where the fuel reaches be ſawed away. The moſt convenient cover for it, is an iron plate with a round hole in the middle, and a handle projecting at one ſide for lifting it. (Letter A.)

The force of the fire being thus in a great meaſure concentrated upon the crucible in the middle of the fuel, the crucible is heated expeditiouſly, and with a little quantity of fuel, to a very intenſe degree; while the exterior parts of the furnace are of no great heat, and permit the operator to approach without incommoding him.

Blow-pipe.

Every effect of the moſt violent heat of furnaces may be produced by the flame of a candle, or lamp, urged upon a ſmall particle of any ſubſtance by the blow-pipe. This inſtrument is ſold by the ironmongers; and conſiſts merely of a braſs pipe, about one eighth of an inch diameter at one end, and the other tapering to a much leſs ſize, with a very ſmall perforation for the wind to eſcape. The ſmaller end is bended on one ſide. For philoſophical, or other nice purpoſes, the blow-pipe is provided with a bowl, or enlargment, B, (fig. 14), in which the vapours of the breath are condenſed and detained; and alſo with three or four ſmall nozzles, with different apertures, to be ſlipped on the ſmaller extremity. Theſe are of uſe when larger or ſmaller flames are to be occaſionally uſed; becauſe a larger flame requires a larger aperture, in order that the air may effectually urge it upon the matter under examination.

Artifice of blowing through the pipe.

There is an artifice in the blowing through this pipe, which is more difficult to deſcribe than to acquire. The effect intended to be produced is a continual ſtream of air for many minutes, if neceſſary, without ceaſing. This is done by applying the tongue to the roof of the mouth,

APPLICAT. OF HEAT.

mouth, ſo as to interrupt the communication between the mouth and the paſſage of the noſtrils: by which means the operator is at liberty to breathe through the noſtrils, at the ſame time that, by the muſcles of the lips, he forces a continual ſtream of air from the anterior part of the mouth through the blow-pipe. When the mouth begins to be empty, it is repleniſhed by the lungs in an inſtant; while the tongue is withdrawn from the roof of the mouth, and replaced again in the ſame manner as in pronouncing the monoſyllable tut. In this way the ſtream may be continued for a long time without any fatigue, if the flame be not urged too impetuouſly; and even in this caſe no other fatigue is felt than that of the muſcles of the lips.

Flame urged by the blow-pipe,

A wax-candle of a moderate ſize, but thicker wick than they are uſually made with, is the moſt convenient for occaſional experiments; but a tallow-candle will do very well. The candle ſhould be ſnuffed rather ſhort, and the wick turned on one ſide towards the object, ſo that a part of it ſhould lie horizontal. The ſtream of air muſt be blown along this horizontal part as near as may be without ſtriking the wick. If the flame be ragged and irregular, it is a proof that the hole is not round or ſmooth; and if the flame have a cavity through it, the aperture of the pipe is too large. When the hole is of a proper figure, and duly proportioned, the flame conſiſts of a neat luminous blue cone, ſurrounded by another flame of a more faint and indiſtinct appearance. The ſtrongeſt heat is at the point of the inner flame.

The ſubject to be heated.

The body intended to be acted on by the blow-pipe, ought not to exceed the ſize of a pepper-corn. It may be laid upon a piece of cloſe-grained well-burned charcoal, unleſs it be of ſuch a nature as to ſink into the pores of that ſubſtance, or to have its properties affected by its inflammable quality. Such bodies may be placed in a ſmall ſpoon made of pure gold, or ſilver, or platina.

Advantages of the blow-pipe:

Many great advantages may be derived from the uſe of this ſimple and valuable inſtrument. Its ſmallneſs, which renders it ſuitable to the pocket, is no inconſiderable recommendation. The moſt expenſive materials, and the minuteſt ſpecimens of bodies, may be uſed in theſe experiments; and the whole proceſs, inſtead of being carried on in an opake veſſel, is under the eye of the obſerver from beginning to end. It is true that very little can be determined in this way concerning the quantities of products; but in moſt caſes a knowledge of the contents of any ſubſtance is a great acquiſition, which is thus obtained in a very ſhort time, and will at all events ſerve to ſhew the beſt and leaſt expenſive way of conducting proceſſes with the ſame matters in the larger way.

—its uſe rendered eaſy by bellows.

The blow-pipe * has deſervedly of late years been conſidered as an eſſential inſtrument in a chemical laboratory; and ſeveral attempts have been made to facilitate its uſe by the addition of bellows, or ſome other equivalent inſtrument. Theſe are doubtleſs very convenient, though they render it leſs portable for mineralogical reſearches. It will not here be neceſſary to enter into any deſcription of a pair of double bellows fixed under a table, and communicating with a blow-pipe

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* See Magellan's edition of Cronſtedt's Mineralogy, or Bergmann's Chemical Eſſays.

APPLICAT. OF HEAT.

which paſſes through the table. Smaller bellows, of a portable ſize for the pocket, have been made for the ſame purpoſe. The ingenious chemiſt will find no great difficulty in adapting a bladder to the blow-pipe, which, under the preſſure of a board, may produce a conſtant ſtream of air; and may be repleniſhed, as it becomes empty, by blowing into it with bellows, or the mouth, at another aperture furniſhed with a valve opening inwards.

Blow-pipe with vital air.

The chief advantage theſe contrivances have over the common blow-pipe is, that they may be filled with vital or dephlogiſticated air, which increaſes the activity of combuſtion to an aſtoniſhing degree.

CHAP. V.

CONCERNING THE METHODS OF MAKING EXPERIMENTS ON BODIES IN THE FLUID AND IN THE AERIFORM STATE.

PROCESSES WITHOUT HEAT.

FROM the preceding chapter, the methods of conducting proceſſes, in which conſiderable heat is required, may be eaſily underſtood. Little need be ſaid concerning the manner of making experiments with fluid bodies in the common temperature of the atmoſphere. Baſons, cups, phials, mattraſſes, and other ſimilar veſſels, form the whole apparatus required for the purpoſe of containing the matters intended to be put together; and no other precaution or inſtruction is required, than to uſe a veſſel of ſuch materials as ſhall not be corroded or acted upon by its contents, and of ſufficient capacity to admit of any ſudden expanſion, or frothing of the fluid, if expected. This veſſel muſt be placed in a current of air, if noxious fumes ariſe, in order that theſe may be blown from the operator.

Apparatus for denſe fluids.

The method of making experiments with permanently elaſtic fluids or air, though ſimple, is not ſo obvious. We live immerſed in an atmoſphere not greatly differing in denſity from theſe fluids; which are not, for that reaſon, ſufficiently ponderous to be detained in open veſſels by their weight. Their remarkable levity, however, affords a method of confining them, by means of other denſer fluids. Dr. Prieſtley, whoſe labours have ſo far exceeded thoſe of his predeceſſors and cotemporaries, both in extent and importance, that he

— for elaſtic fluids.

PROCESSES WITHOUT HEAT.

Apparatus for experiments with elaſtic fluids.

may with juſtice be ſtyled the father of this important branch of natural philoſophy, uſes the following apparatus.

Fig. 15. A repreſents a wooden veſſel, or tub; K, K, K, is a ſhelf fixed in the tub. When this apparatus is uſed, the tub is to be filled with water to ſuch an height, as to riſe about one inch above the upper ſurface of the ſhelf. B, G, F, are glaſs jars inverted with their mouths downwards, which reſt upon the ſhelf. If theſe, or any other veſſels open only at one end, be plunged under the water, and inverted after they are filled, they will remain full, notwithſtanding their being raiſed out of the water, provided their mouths be kept immerſed; for in this caſe the water is ſuſtained by the preſſure of the atmoſphere in the ſame manner as the mercury in the barometer. It may without difficulty be imagined, that if common air, or any other fluid reſembling common air in lightneſs and elaſticity, be ſuffered to enter theſe veſſels, it will riſe to the upper part, and the ſurface of the water will ſubſide. If a bottle, a cup, or any other veſſel in that ſtate which is uſually called empty, though really full of air, be plunged into the water with its mouth downwards, ſcarcely any water will enter, becauſe its entrance is oppoſed by the elaſticity of the included air; but if the veſſel be turned up, it immediately fills, and the air riſes in one or more bubbles to the ſurface. Suppoſe this operation to be performed under one of the jars which are filled with water: the air will aſcend as before; but, inſtead of eſcaping, it will be detained in the upper part of the jar. In this manner, therefore, we ſee that air may be emptied out of one veſſel into another, by an inverted pouring, in which

Apparatus for experiments with elaſtic fluids.

which the air is made to aſcend from the lower to the upper veſſel, in which the experiments are performed, by the action of the weightier fluid, exactly ſimilar to the common pouring of denſer fluids, detained in the bottoms of open veſſels, by the ſimple action of gravity. When the receiving veſſel has a narrow neck, the air may be poured through a glaſs funnel, H.

Body and tube.

C (fig. 15) is a glaſs body or bottle, whoſe bottom is blown very thin, that it may ſupport the heat of a candle, ſuddenly applied, without cracking. In its neck is fitted, by grinding, a tube D, curved nearly in the form of the letter S. This kind of veſſel is very uſeful in various chemical operations, for which it will be convenient to have them of ſeveral ſizes. In the figure, the body C is repreſented as containing a fluid, in the act of combining with a ſubſtance that gives out air, which paſſes through the tube into the jar B, under whoſe mouth the other extremity of the tube is placed. At E is a ſmall retort of glaſs or earthen ware, whoſe neck being plunged in the water, beneath the jar F, is ſuppoſed to emit the elaſtic fluid, extricated from the contents of the retort, which is received in the jar.

Stand or ſupport of wire.

When any thing, as a gallipot, is to be ſupported at a conſiderable height within a jar, it is convenient to have ſuch wire ſtands as are repreſented fig. 16. Theſe anſwer better than any other, becauſe they take up but little room, and are eaſily bended to any figure or height.

Gun-barrel.

In order to expel air from ſolid ſubſtances by means of heat, a gun-barrel, with the touch-hole ſcrewed up and rivetted, may be uſed inſtead of an iron retort.

APPARATUS FOR ELASTIC FLUIDS.

The ſubject may be put in the chamber of the barrel, and the reſt of the bore may be filled with dry ſand, that has been well burned, to expel whatever air it might have contained. The ſtem of a tobacco-pipe, or a ſmall glaſs tube, being luted in the orifice of the barrel, the other extremity muſt be put into the fire, that the heat may expel the air from its contents. This air will of courſe paſs through the tube, and may be received under an inverted veſſel, in the uſual manner:

Phials with quickſilver.

But the moſt accurate method of procuring air from ſeveral ſubſtances, by means of heat, is, to put them, if they will bear it, into phials full of quickſilver, with the mouths inverted in the ſame, and then throw the focus of a burning lens or mirror upon them. For this purpoſe their bottoms ſhould be round, and very thin, that they may not be liable to fly with the ſudden application of heat. The body c anſwers this purpoſe very well.

Burning lens, or mirror.

Apparatus with mercury.

Many kinds of air combine with water, and therefore require to be treated in an apparatus in which quickſilver is made uſe of. This fluid being very ponderous, and of conſiderable price, it is an object of convenience as well as œconomy, that the trough and veſſels ſhould be ſmaller than when water is uſed.

Combuſtion of air.

When trial is to be made of any kind of air, whether it be fit for maintaining combuſtion, the air may be put in a long narrow glaſs veſſel, whoſe mouth being carefully covered, may be turned upward. A bit of wax candle being then faſtened to the end of a wire, which is bended ſo that the flame of the candle may be

upper-

APPARATUS FOR ELASTIC FLUIDS.

uppermoſt, is to be let down into the veſſel, which muſt be kept covered till the inſtant of plunging the lighted candle in the air.

Meaſuring tubes.

Where the change of dimenſions, which follows from the mixture of ſeveral kinds of air, is to be aſcertained, a graduated narrow cylindrical veſſel may be made uſe of. The graduations may be made by pouring in ſucceſſive equal meaſures of water into this veſſel, and marking its ſurface at each addition. The meaſure may be afterwards uſed for the different kinds of air; and the change of dimenſions will be ſhewn by the riſe or fall of the mercury, or water, in the graduated veſſel. The purity of common air being determinable by the diminution produced by the addition of nitrous air, theſe tubes have been called eudiometer tubes. There are inſtruments called eudiometers, which conſiſt of an aſſemblage of parts adapted to the due mixture of theſe airs, and the accurate meaſurement of the change of bulk they undergo.

Eudiometers.

Management of powders.

There are ſome ſubſtances, more eſpecially powders, which cannot conveniently be put in a phial, or paſſed through a fluid. When air is to be extricated from, or added to, theſe, there is no better method than to place them on a ſtand under the receiver of the air-pump, and exhauſt the common air, inſtead of excluding it by water or mercury. This proceſs requires a good air-pump and careful management, otherwiſe the common air will not be well excluded.

Electric ſpark.

It is frequently an intereſting object to paſs the electric ſpark through different kinds of air, either alone or mixed together. In this caſe a metallic wire may be faſtened in the upper end of a tube, and the ſparks,

APPARATUS FOR ELASTIC FLUIDS.

Electricity applied.

or ſhock, may be paſſed through this wire to the mercury or water uſed to confine the air. If there be reaſon to apprehend that an expanſion in the air may remove the mercury or water beyond the ſtriking diſtance, another wire may be thruſt up to receive the electricity, or two wires may be cemented into oppoſite holes in the ſides of an hermetically ſealed tube.

Holes drilled in glaſs.

Holes may be made in glaſs for this and other chemical uſes, by a drill of copper, or ſoft iron, with emery and water; and, where this inſtrument is wanting, a ſmall round file with water will cut a notch in ſmall veſſels, ſuch as phials or tubes, though with ſome danger of breaking them. In ſome electrical experiments of the kind here mentioned, there is reaſon to expect a fallacious reſult from the wires being burned by the exploſion, or ſpark. For this reaſon the electricity may be made to paſs through the legs of a ſyphon, containing the air which is under conſideration in the upper part of its curvature. One of the veſſels in which the legs of the ſyphon reſt, muſt therefore be inſulated; and if any watery fluid be uſed to confine the air, it is generally ſuppoſed that no conbuſtion takes place.

Impregnation of water;

—with fixed air.

The proceſs of impregnating water with any aerial fluid it will combine with, does not require any particular apparatus, but may be performed with ſuch utenſils as are every where to be met with. The moſt uſual operation of this kind is that of impregnating water with fixed air; which may be done in the following manner. The quart bottle C, fig. 17, is filled with water, and inverted into the baſon F, which likewiſe contains a little water. The inverſion may be eaſily

APPARATUS FOR ELASTIC FLUIDS.

eaſily managed, without any of the contents of the bottle eſcaping, if its orifice be covered with a card, to be withdrawn after the immerſion. A is a half-pint phial, into which broken pieces of marble or chalk are put; and upon them is poured as much water, rendered very acid by a mixture of oil of vitriol, as may fill the bottle two-thirds. B is a bladder, whoſe neck is tied faſt round a perforated cork of a tapering figure. After the efferveſcence of the chalk and the acid has begun, the cork is to be thruſt into the neck of the phial A, the bladder being previouſly emptied by preſſure. Fixed air will eſcape from the chalk, and inflate the bladder. When this laſt is full, it muſt be diſengaged from the bottle, and the bended tube E muſt be thruſt into the orifice of its cork. The aperture of the tube being then placed beneath the mouth of the bottle C, it is eaſy to diſcharge the aerial contents of the bladder by preſſure into this laſt. Agitation of the bottle C, without withdrawing its neck out of the water, increaſes the contact of the air and water, by dividing them into ſmall parts, and by that means cauſes the abſorption to take place in a few ſeconds. Two or three repetitions of this proceſs impregnates the water ſo fully, that it will abſorb no more in this way. The Pyrmont water is of this kind.

The uſe of the bladder, in this operation, is only to prevent any of the fluid contents of the bottle A from paſſing into the bottle C, which would happen in the violent ſtate of ebullition, if the tube E were to paſs directly from the bottle A to C. The manipulation is ſimpler if the bladder have two holes at its oppoſite

APPARATUS FOR ELASTIC FLUIDS.

ends, the one containing a cork, conſtantly kept in the neck of the bottle A, and the other faſtened round the tube E, which then remains conſtantly beneath the mouth of C; and the air is preſſed up as occaſion may demand. See fig. 18.

Dr. Nooth's apparatus.

When habitual uſe is made of water impregnated with fixed air, the apparatus of Dr. Nooth is very effectual and convenient. It conſiſts of three glaſs veſſels (fig. 19). The lower veſſel C contains the effervеſcent materials: it has a ſmall orifice at D, ſtopped with a ground ſtopper, at which an additional ſupply of either acid, or water, or chalk, may be occaſionally introduced. The middle veſſel B is open both above and below. Its inferior neck is fitted by grinding into the neck H of the lower veſſel. In the former is a glaſs valve, formed by two pieces of tube, and a lens, which is moveable, between them, as repreſented in fig. 20. This valve opens upwards, and ſuffers the air to paſs; but the water cannot return through the tubes, partly becauſe the orifice is capillary, and partly becauſe the flat lens covers the hole. The middle veſſel is furniſhed with a cock E, to draw off its contents. The upper veſſel A is fitted, by grinding, into the upper neck of the middle veſſel. Its inferior part conſiſts of a tube, that paſſes almoſt as low as the centre of the middle veſſel. Its upper orifice is cloſed by a ground-ſtopper F. When this apparatus is to be uſed, the effervеſcent materials are put into the lower veſſel; the middle veſſel is filled with pure water, and put in its place; and the upper veſſel is nearly ſtopped, and likewiſe put in its place. The conſequence is, that

APPARATUS FOR ELASTIC FLUIDS.

Dr. Nooth's apparatus:

that the fixed air, paſſing through the valve at H, aſcends into the upper part of the middle veſſel B, where, by its elaſticity, it re-acts on the water, and forces part up the tube into the veſſel A; part of the common air, in this laſt, being compreſſed, and the reſt eſcaping by the ſtopper, which is made of a conical figure, that it may be eaſily raiſed. As more fixed air is extricated, more water riſes, till at length the water in the middle veſſel falls below the lower orifice of the tube. Fixed air then paſſes through the tube into the upper veſſel, and expels more of the common air by raiſing the ſtopper. In this ſituation the water in both veſſels, being in contact with a body of fixed air, becomes ſtrongly impregnated with that fluid, after a certain time. This effect may be haſtened by taking off the middle and upper veſſels together, and agitating them.

—its valve defective.

The valve is the moſt defective part of this apparatus: for the capillary tube does not admit the air through, unleſs there be a conſiderable quantity condenſed in the lower veſſel: and the condenſation has, in ſome inſtances, burſt the veſſel.

Improvements in diſtillation.

Modern diſcoveries, reſpecting bodies in the aeriform ſtate, have produced ſeveral capital improvements in the veſſels uſed for diſtillation. It was common with the earlier chemiſts to make a ſmall hole in the upper part of their retorts, that the elaſtic vapours might eſcape, which would otherwiſe have burſt the veſſels. By this means they loſt a very conſiderable part of their products. Fig. 21, is an apparatus of veſſels*,

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* Prieſtley, III.

VESSELS FOR DISTILLING.

Combination of receivers.

in which all the products may be examined. A is a mattraſs, which communicates with the receiver B, by a tube that reaches very near the bottom of the latter. The upper part of this receiver communicates in the ſame manner with the ſecond receiver C, by a tube reaching nearly to the bottom of C. In like manner C communicates with D, and from D proceeds a recurved tube, which may be inſerted beneath an inverted veſſel of water, or mercury. It is evident, in this apparatus, that whatever volatile matter eſcapes from the veſſel A, by heat or otherwiſe, will either be condenſed in B, C, or D; and that the aerial products will paſs through the whole ſet, and through the recurved tube, into the inverted veſſel. Theſe receivers may be more or leſs numerous, according to circumſtances; and the volatile products may be condenſed in, or made to paſs through, water, oil, or any other fluids placed in either of the receivers. The tubes may be either fitted in with cork and cement; or, which is better, but more expenſive, by grinding. Small veſſels of this kind form a convenient interruption in the recurved tube, paſſing from a bottle containing matters that give out air, as they are preferable in cloſeneſs and neatneſs to a bladder.

Improved receiver.

Fig. 22, Exhibits an improvement in the receiver in diſtillation*. A is the retort. B an intermediate veſſel, called an adopter, which is only occaſionally uſed. C the receiver, having two necks; one at D, inſerted into a bottle which receives the products which are

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* By Mr. Woulfe. Prieſtley, III.

uſually

VESSELS FOR DISTILLING.

uſually condenſed in the receiver; and the other, at E, tranſmits the more volatile or aeriform products into a baſon G, containing water; beneath the ſurface of which the extremity of the neck E is plunged. It is obvious that this apparatus is more particularly uſeful when the products are ſuch as combine with the fluids in G, and would otherwiſe eſcape; and it is hardly neceſſary to obſerve, that a bottle, or other convenient veſſel, may be ſubſtituted inſtead of the baſon G.

Remedy againſt abſorption.

It often happens in chemical proceſſes, from the irregularity of the heat, or from other circumſtances, that the condenſation is more rapid, in proportion to the ſupply of vapour, at ſome periods of the ſame operation than at others. Whenever this takes place, the elaſticity of the vapours will not be equal to the external preſſure of the air; and if any orifice of the veſſels, which are in other reſpects cloſed, be plunged in water, or any other fluid, this laſt will be preſſed into the veſſels. The remedy for this inconvenience is, to plunge the neck of the veſſel to no greater depth in the water, than that the fall of the water, in the receiving veſſel, may leave the orifice open for the admiſſion of air, before the water has riſen high enough above the orifice to reach the contents of the veſſels. This effect is increaſed by making the neck large, in proportion to the diameter of the veſſel which contains the water. Thus, if the neck E be made large, and the water from the baſon G ſhould, by a rapid condenſation in C, be forced up the neck, the ſurface of the water in G will fall ſo much as to leave the lower orifice of E uncovered, before any conſiderable riſe can

Remedy againſt abſorption:

take place; but if F were narrower, its whole capacity would be filled, and the water would run over into C before the fall in G would be ſufficient to uncover the orifice of F, and reſtore the equilibrium, by admitting common air. This obſervation applies to all chemical veſſels, and is in no caſe more eſſential than when the neck of a ſimple retort is plunged in water contained in a receiver.

—of Chaptal.

The above contrivance, which is Mr. Babington's, cannot very conveniently be applied to the apparatus Fig. 21, in which nevertheleſs the condenſation of elaſtic matter in the retort might occaſion a diſagreeable return of the fluids from the reſpective bottles in ſucceſſion. Chaptal remedies this by a very ſimple expedient. He has the tube of communication between A and B rather too ſhort to reach the liquid in B; and through the bottom or upper part of this inverted receiver B he paſſes a ſmall tube open at both ends, and plunged into the liquid. This communication with the external air has no perceptible effect, as far as relates to any eſcape of the vapours; though it effectually remedies the conſequences of abſorption.

CHAP.

C H A P. VI.

CONCERNING THE BALANCE AND WEIGHTS, WITH A COMPARATIVE TABLE OF THE VARIOUS WEIGHTS MADE USE OF IN EUROPE.

THE BALANCE.

THE beginning and end of every exact chemical proceſs conſiſt in weighing. With imperfect inſtruments this operation will be tedious and inaccurate: but, with a good balance, the reſults will be ſatisfactory; and much time, which is ſo precious in experimental reſearches, will be ſaved. I have not, therefore, thought it improper to devote a whole chapter to this general and important ſubject; by the help of which, if attentively conſidered, the chemical ſtudent may learn to diſtinguiſh a good inſtrument, or correct the errors of a bad one.

Balance deſcribed.

The balance is a lever, whoſe axis of motion is formed with an edge like that of a knife; and the two diſhes at its extremities are hung upon edges of the ſame kind. Theſe edges are firſt made ſharp, and then rounded with a fine hone, or a piece of buff leather. The excellence of the inſtrument depends, in a great meaſure, on the regular form of this rounded part. When the lever is conſidered as a mere line, the two outer edges are called points of ſuſpenſion, and the inner the fulcrum. The points of ſuſpenſion are ſuppoſed to be at equal diſtances from the fulcrum, and to be preſſed with equal weights when loaded.

Points of ſuſpenſion.

Fulcrum.

1. If

THE BALANCE.

Propoſitions.

1. If the fulcrum be placed in the center of gravity of the beam, and the three edges lie all in the ſame right line, the balance will have no tendency to one poſition more than another; but will reſt in any poſition it may be placed in, whether the ſcales be on or off, empty or loaded.

2. If the center of gravity of the beam, when level, be immediately above the fulcrum, it will overſet by the ſmalleſt action; that is, the end which is loweſt will deſcend: and it will do this with more ſwiftneſs the higher the center of gravity, and the leſs the points of ſuſpenſion are loaded.

3. But if the center of gravity of the beam be immediately below the fulcrum, the beam will not reſt in any poſition but when level; and, if diſturbed from that poſition, and then left at liberty, it will vibrate, and at laſt come to reſt on the level. Its vibrations will be quicker, and its horizontal tendency ſtronger, the lower the center of gravity, and the leſs the weight upon the points of ſuſpenſion.

4. If the fulcrum be below the line joining the points of ſupenſion, and theſe be loaded, the beam will overſet, unleſs prevented by the weight of the beam tending to produce an horizontal poſition; as in § 3. In this laſt caſe, ſmall weights will equilibrate, as in § 3; a certain exact weight will reſt in any poſition of the beam, as in § 1; and all greater weights will cauſe the beam to overſet, as in § 2. Money ſcales are often made this way, and will overſet with any conſiderable load.

Money ſcales.

5. If the fulcrum be above the line joining the points of ſuſpenſion, the beam will come to the horizontal

THE BALANCE.

Propoſitions.

zontal poſition, unleſs prevented by its own weight, as in § 2. If the center of gravity of the beam be nearly in the fulcrum, all the vibrations of the loaded beam will be made in times nearly equal, unleſs the weights be very ſmall, when they will be ſlower. The vibrations of balances are quicker; and the horizontal tendency ſtronger, the higher the fulcrum.

6. If the arms of a balance be unequal, the weights in equipoiſe will be unequal in the ſame proportion. It is a ſevere check upon a workman to keep the arms equal, while he is making the other adjuſtments in a ſtrong and inflexible beam.

Weighing with a balance which is not equibrachial.

7. The equality of the arms of a balance is of uſe, in ſcientific purſuits, chiefly in the making of weights by biſection. A balance with unequal arms will weigh as accurately as another of the ſame workmanſhip with equal arms, provided the ſtandard weight itſelf be firſt counterpoiſed, then taken out of the ſcale, and the thing to be weighed be put into the ſcale, and adjuſted againſt the counterpoiſe. Or, when proportional quantities only are conſidered, as in chemical and other philoſophical experiments, the bodies and products under examination may be weighed againſt the weights, taking care always to put the weights in the ſame ſcale. For then, though the bodies may not be really equal to the weights, yet their proportions amongſt each other will be the ſame as if they had been accurately ſo.

8. But though the equality of the arms may be well diſpenſed with, yet it is indiſpenſably neceſſary that their relative lengths, whatever they may be, ſhould continue invariable. For this purpoſe, it is neceſſary

either that the three edges be all truly parallel, or that the points of ſuſpenſion and ſupport ſhould be always in the ſame part of the edge. This laſt requiſite is the moſt eaſily obtained.

Conſtruction.

The balances made in London are uſually conſtructed in ſuch a manner, that the bearing parts form notches in the other parts of the edges; ſo that the ſcales being ſet to vibrate, all the parts naturally fall into the ſame bearing. The balances made in the country have the fulcrum edge ſtraight, and confined to one conſtant bearing by two ſide plates. But the points of ſuſpenſion are referred to notches in the edges, like the London balances. The balances here mentioned, which come from the country, are incloſed in a ſmall iron japanned box; and are to be met with at the Birmingham and Sheffield warehouſes, though leſs frequently than ſome years ago; becauſe a pocket contrivance for weighing guineas and half guineas has got poſſeſſion of the market. They are, in general, well made and adjuſted, turn with the twentieth of a grain when empty, and will ſenſibly ſhew the tenth of a grain, with an ounce in each ſcale. Their price is from five ſhillings to half-a-guinea; but thoſe which are under ſeven ſhillings have not their edges hardened, and conſequently are not durable. This may be aſcertained by the purchaſer, by paſſing the point of a penknife acroſs the ſmall piece which goes through one of the end boxes; if it makes any mark or impreſſion, the part is ſoft.

The turn.

9. If a beam be adjuſted ſo as to have no tendency to any one poſition, as in § 1, and the ſcales be equally loaded; then, if a ſmall weight be added in one of the

ſcales,

THE BALANCE.

Propoſitions.

ſcales, that balance will turn, and the points of ſuſpenſion will move with an accelerated motion, ſimilar to that of falling bodies; but as much ſlower in proportion, very nearly, as the added weight is leſs than the whole weight borne by the fulcrum.

10. The ſtronger the tendency to an horizontal poſition in any balance, or the quicker its vibrations, § § 3, 5, the greater additional weight will be required to cauſe it to turn or incline to any given angle. No balance therefore can turn ſo quick as the motion deduced in § 9. Such a balance as is there deſcribed, if it were to turn with the ten thouſandth part of the weight, would move at quickeſt ten thouſand times ſlower than a falling body; that is, the diſh containing the weight, inſtead of falling through ſixteen feet in a ſecond of time, would fall through only two hundredth parts of an inch, and it would require four ſeconds to move through one third part of an inch: conſequently, all accurate weighing muſt be ſlow. If the indexes of two balances be of equal lengths, that index which is connected with the ſhorter balance will move proportionally quicker than the other. Long beams are he moſt in requeſt, becauſe they are thought to have eſs friction. This is doubtful: but the quicker angular motion, greater ſtrength, and leſs weight, of a hort balance, are certain advantages.

Accurate weighing is ſlow.

Long beams.

11. Very delicate balances are not only uſeful in ice experiments, but are likewiſe much more expeitious than others in common weighing. If a pair of ſcales, with a certain load, be barely ſenſible to the ne-tenth of a grain, it will require a conſiderable me to aſcertain the weight to that degree of accuracy, becauſe

THE BALANCE.

Propoſitions.

becauſe the turn muſt be obſerved ſeveral times over, and is very ſmall. But if no greater accuracy were required, and ſcales were uſed which would turn with the hundredth of a grain, a tenth of a grain more or leſs would make ſo great a difference in the turn, that it would be ſeen immediately.

12. If a balance be found to turn with a certain addition, and is not moved by any ſmaller weight, a greater ſenſibility may be given to that balance, by producing a tremulous motion in its parts. Thus, if the edge of a blunt ſaw, a file, or other ſimilar inſtrument, be drawn along any part of the caſe or ſupport of a balance, it will produce a jarring, which will diminiſh the friction on the moving parts ſo much, that the turn will be evident with one third or one fourth of the addition that would elſe have been required. In this way a beam which would barely turn by the addition of the tenth of a grain, will turn with the thirtieth or fortieth of a grain.

13. A balance whoſe horizontal tendency depends only on its own weight, as in § 3, will turn with the ſame addition, whatever may be the load: except ſo far as a greater load will produce a greater friction.

14. But a balance whoſe horizontal tendency depends only on the elevation of the fulcrum, as in § 5, will be leſs ſenſible the greater the load; and the addition requiſite to produce an equal turn will be in proportion to the load itſelf.

15. In order to regulate the horizontal tendency in ſome beams, the fulcrum is placed below the points of ſuſpenſion, as in § 4, and a ſliding weight is put upon the cock or index; by means of which the centre of gravity

THE BALANCE.

gravity may be raiſed or depreſſed. This is an uſeful contrivance.

Sets of weights.

Common pile.

Biſection.

Wire rings.

16. Weights are made by a ſubdiviſion of a ſtandard weight. If the weight be continually halved, it will produce the common pile, which is the ſmalleſt poſſible number for weighing between its extremes, without placing any weight in the ſcale with the body under examination. Granulated lead is a very convenient ſubſtance to be uſed in this operation of halving, which however is very tedious. The readieſt way to ſubdivide ſmall weights, conſiſts in weighing a certain quantity of ſmall wire, and afterwards cutting it into ſuch parts, by meaſure, as are deſired. Or the wire may be wrapped cloſe round two pins, and then cut aſunder with a knife. By this means it will be divided into a great number of equal lengths, or ſmall rings. The wire ought to be ſo thin, as that one of theſe rings may barely produce a ſenſible effect on the beam. If any quantity (as, for example, a grain) of theſe rings be weighed, and the number then reckoned, the grain may be ſubdivided in any proportion, by dividing that number, and making the weights equal to as many of the rings as the quotient of the diviſion denotes. Then, if 750 of the rings amounted to a grain, and it were required to divide the grain decimally, downwards, $\frac{9}{10}$ would be equal to 675 rings, $\frac{8}{10}$ would be equal to 600 rings, $\frac{7}{10}$ to 525 rings, &c. Small weights may be made of thin leaf braſs. Jewellers foil is a good material for weights below the $\frac{1}{10}$ of a grain, as low as to the $\frac{1}{100}$ of a grain; and all lower quantities may be either eſtimated by the poſition of the index, or ſhewn by actually counting

ing the rings of wire, whoſe value has been determined.

Number of weights required to form a ſet.

17. In philoſophical experiments, it will be found very convenient to admit no more than one dimenſion of weight. The grain is of that magnitude as to deſerve the preference. With regard to the number of weights the chemiſt ought to be provided with, writers have differed according to their habits and views. Mathematicians have computed the leaſt poſſible number with which all weights, within certain limits, might be aſcertained; but their determination is of little uſe, becauſe, with ſo ſmall a number, it muſt often happen, that the ſcales will be heavily loaded with weights, on each ſide, put in with a view only to determine the difference between them. It is not the leaſt poſſible number of weights which it is neceſſary an operator ſhould buy to effect his purpoſe, that we ought to enquire after, but the moſt convenient number for obtaining the reſults with accuracy and expedition. The error of adjuſtment is the leaſt poſſible, when only one weight is in the ſcale; that is, a ſingle weight of five grains is twice as likely to be true, as two weights, one of three, and the other of two grains, put into the diſh to ſupply the place of the ſingle five, becauſe each of theſe laſt has its own probability of error in adjuſtment. But, ſince it is as inconſiſtent with convenience to provide a ſingle weight, as it would be to have a ſingle character for every number; and as we have nine characters, which we uſe in rotation, to expreſs higher values according to their poſition; it will be found very ſerviceable to make the ſet of weights correſpond with our numerical ſyſtem.

Decimal ſet of weights.

ſyſtem. This directs us to the ſet of weights, as follows: 1000 grains, 900 g. 800 g. 700 g. 600 g. 500 g. 400 g. 300 g. 200 g. 100 g. 90 g. 80 g. 70 g. 60 g. 50 g. 40 g. 30 g. 20 g. 10 g. 9 g. 8 g. 7 g. 6 g. 5 g. 4 g. 3 g. 2 g. 1 g. $\frac{9}{10}$ g. $\frac{8}{10}$ g. $\frac{7}{10}$ g. $\frac{6}{10}$ g. $\frac{5}{10}$ g. $\frac{4}{10}$ g. $\frac{3}{10}$ g. $\frac{2}{10}$ g. $\frac{1}{10}$ g. $\frac{9}{100}$ g. $\frac{8}{100}$ g. $\frac{7}{100}$ g. $\frac{6}{100}$ g. $\frac{5}{100}$ g. $\frac{4}{100}$ g. $\frac{3}{100}$ g. $\frac{2}{100}$ g. $\frac{1}{100}$ g. With theſe the philoſopher will always have the ſame number of weights in his ſcales as there are figures in the number expreſſing the weights in grains.

Thus 742.5 grains will be weighed by the weights 700, 40, 2, and $\frac{5}{10}$.

Account of ſome balances.

I ſhall conclude this chapter with an account of ome balances I have ſeen or heard of, and annex a able of the correſpondence of weights of different ountries.

The balance of Muſchenbroek:

Muſchenbrock, in his Cours de Phyſique (French ranſlation, Paris, 1769), tom. ii. p. 247, ſays, he ſed an ocular balance of great accuracy, which turned rebuchoit) with $\frac{1}{40}$ of a grain. The ſubſtances he eighed were between 200 and 300 grains. His ba-nce, therefore, weighed to the $\frac{1}{12000}$ part of the hole; and would aſcertain ſuch weights truly to four aces of figures.

— of Bolton.

In the Philoſophical Tranſactions, vol. lxvi. p. 509, ention is made of two accurate balances of Mr. olton; and it is ſaid that one would weigh a pound, id turn with $\frac{1}{10}$ of a grain. This, if the pound be oirdupois, is $\frac{1}{70000}$ of the weight; and ſhews that e balance could be well depended on to four places figures, and probably to five. The other weighed half an ounce, and turned with the $\frac{1}{100}$ of a grain. This is the $\frac{1}{24000}$ of the weight.

Balance of Mr. Read:

In the ſame ſame volume, p. 511, a balance of Mr. Read's is mentioned, which readily turned with leſs than one pennyweight, when loaded with 55 pounds, before the Royal Society; but very diſtinctly turned with four grains when tried more patiently. This is about the $\frac{1}{96000}$ part of the weight; and therefore this balance may be depended on to five places of figures.

—of Mr. Whitehurſt:

Alſo, p. 576, a balance of Mr. Whitehurſt's weighs one pennyweight, and is ſenſibly affected with the $\frac{1}{2000}$ of a grain. This is $\frac{1}{48000}$ part of the weight.

—of the Author:

I have a pair of ſcales of the common conſtruction, § 8, made expreſsly for me by a ſkilful workman in London. With 1200 grains in each ſcale, it turns with $\frac{1}{70}$ of a grain. This is the $\frac{1}{84000}$ of the whole; and therefore about this weight may be known to five places of figures. The proportional delicacy is leſs in greater weights. The beam will bear near a pound troy, and when the ſcales are empty it is affected by the $\frac{1}{1000}$ of a grain. On the whole, it may be uſefully applied to determine all weights between 100 grains and 4000 grains to four places of figures.

—of Mr. Alchorne:

A balance belonging to Mr. Alchorne, of the Mint, in London, is mentioned, vol. lxxvii. p. 205 of the Philoſophical Tranſactions. It is true to 3 grains with 15 lb. an end. If theſe were avoirdupois pounds, the weight is known to $\frac{1}{35000}$ part, or to four places of figures, or barely five.

—of Dr. Geo. Fordyce.

A balance (made by Ramſden, and turning on points inſtead of edges) in the poſſeſſion of Dr. George Fordyce, is mentioned in the 75th volume of the Philoſophical Tranſactions. With a load of four or five ounces, a difference of one diviſion in the index was made by the $\frac{1}{1600}$ of a grain. This is $\frac{1}{384000}$ part of the weight; and, conſequently, this beam will aſcertain ſuch weights to five places of figures, beſides an eſtimate figure.

The balance of Mr. Magellan:

I have ſeen a ſtrong balance in the poſſeſſion of my friend Mr. Magellan, of the kind mentioned in § 15, which would bear ſeveral pounds, and ſhewed $\frac{1}{10}$ grain, with one pound an end. This is the $\frac{1}{70000}$ of the weight, and anſwers to five figures. But I think it would have done more by a more patient trial than I had time to make.

—of the Royal Society.

The Royal Society's balance, which was lately made by Ramſden, turns on ſteel edges upon planes of poliſhed cryſtal. I was aſſured that it aſcertained a weight to the ſeven millionth part. I was not preſent at this trial, which muſt have required great care and patience, as the point of ſuſpenſion could not have moved over much more than $\frac{2}{100}$ of an inch in the firſt half minute: but, from ſome trials which I ſaw, I think it probable that it may be uſed in general practice o determine weights to five places and better.

Inferences.

From this account of balances the young ſtudent nay form a proper eſtimate of the value of thoſe ables of ſpecific gravities, which are carried to five, ix, and even ſeven places of figures, and likewiſe of he theoretical deductions in chemiſtry that depend on ſuppoſed accuracy in weighing, which practice does 1ot authoriſe. In general, where weights are given o five places of figures, the laſt figure is an eſtimate

or

THE BALANCE.

or gueſs figure; and where they are carried farther, it may be taken for granted that the author deceives either intentionally, or from want of ſkill in reducing his weights to fractional expreſſions, or otherwiſe.

Compariſon of weights:

Among the numerous public exertions which our learned neighbours, the French, have made in favour of the ſciences, the determination of the relative proportions of the weights uſed in various parts of Europe, is by no means one of the leaſt. The moſt exact ſtandard weights were procured by means of the ambaſſadors of France, reſident in the various places; and

—by Monſ. Tillet.

theſe were compared by Monſ. Tillet with the ſtandard mark in the pile called the *poids de Charlemagne*, preſerved in the Cour de Monnoies at Paris. His experiments were made with an exact balance made to weigh one mark, and ſenſible to one quarter of a grain. Now, as the mark contains 18,432 quarter grains, it follows that his balance was a good one, and would exhibit proportions to four places, and a gueſs figure. The reſults are contained in Table II. (Appendix), extracted from Monſ. Tillet's excellent Paper in the Memoirs of the Royal Academy of Sciences for the year 1767. I have added the two laſt columns, which ſhew the number of French and Engliſh grains contained in the compound quantities againſt which they ſtand. The Engliſh grains are computed to one-tenth of a grain, though the accuracy of weighing came no nearer than about two tenths.

CHAP.

CHAP. VII.

ON THE ATTRACTIONS EXERTED BETWEEN BODIES; PARTICULARLY THOSE WHICH THE CHEMISTS CALL ELECTIVE ATTRACTIONS.

AFFECTIONS OF BODIES.

THUS far we have attended chiefly to the changes produced in bodies by an alteration in their temperature, and to the methods of conducting chemical operations. We now proceed to conſider thoſe actions which take place between the parts of bodies of different kinds. Theſe form a branch of knowledge of the greateſt importance, but of ſuch an extended nature as to require the utmoſt caution to avoid error in endeavouring to acquire it. The whole ſcientific part of chemiſtry depends on a right interpretation of facts of this kind. In the inveſtigation of thoſe general truths which may be conſidered as laws of nature, we cannot therefore be too careful in diſtinguiſhing well-eſtabliſhed facts from the ingenious though inadequate concluſions which theoretical writers are too ready to form.

Great importance of the knowledge of the actions between the parts of bodies.

Inertia of matter.

That property of matter or body by which we think we can beſt determine its quantity, is its inertia, or the reſiſtance it makes to the communication of motion. We cannot perhaps form any idea why there ſhould be more difficulty in moving one body than another, except that it really conſiſts of a larger portion of matter. The perceptible extenſion of the ſame body will vary, if

Extenſion.

ATTRACTIONS.

Gravity may perhaps be modified:

if the dimenſions of its pores be either increaſed or diminiſhed; and there is no inconſiſtency in ſuppoſing it at leaſt poſſible that its weight, or the force by which it is urged towards the earth, may not in all caſes continue unaltered, but be capable of modification like the attractions of magnetiſm and electricity. Neither the extenſion nor the weight of bodies appears therefore to be original meaſures of their quantities of matter; how far they may be uſed as ſuch, muſt depend on their coincidence with the inertia.

—but is not found to vary in experiments.

After a proper allowance has been made for the effects of the earth's rotation on its axis, it is found that the power of gravitation, in giving motion to the balls of pendulums, is accurately in proportion to their maſſes, as meaſured by their reſiſtance or inertia. The weights of bodies therefore are meaſures of their quantities of matter; and though the forces with which various bodies of equal magnitude are urged towards the earth, are different, we do not ſuppoſe the attraction or affinity between thoſe bodies and the earth to be ſtronger or weaker in the ſeveral inſtances, but only that the maſſes are greater or leſs. Thus, though a cubic inch of gold weighs more than twice as much as a cubic inch of copper, we do not ſuppoſe a ſtronger attraction between gold and the earth; but conclude that one general force acts on both, whoſe effects are greater on the former body than the latter, becauſe the maſs of the former is really greater than that of the latter.

Uſual inference.

Effects of attraction:

—cohesive.

The effects of attraction between one body and another are ſo numerous, that we cannot avoid perceiving them every moment. Two ſmooth poliſhed pieces of metal adhere when preſſed together. Water and other fluids take the form of globules, and will ſtick to various bodies, and paſs into the pores of ſponge, bread, or the cavities of ſmall tubes. Solid bodies retain their form by the adheſion of their parts; and without this power it is impoſſible to conceive how the univerſe could, for a moment, ſubſiſt in its preſent form.

Coheſive attraction differs from gravity.

It may be queſtioned whether this coheſive attraction be the ſame power as gravity. To decide the enquiry, it will be neceſſary to compare their manner of action. The force of gravity acts in the inverſe proportion of the ſquare of the diſtance between the bodies: but the effects of coheſion are found to increaſe at a much faſter rate, as the bodies approach; ſo that its power is incomparably greateſt at ſmall diſtances. This ſeems to be a ſufficient reaſon for conſidering gravitation and coheſion as two diſtinct powers.

Elective attraction.

The elective attraction of the chemiſts—ſuch, for example, as when copper, being diſſolved in an acid, is ſeparated, and falls to the bottom in a powdery form, on the addition of iron—may, in all its numerous varieties, be either one general power, acting like gravity, according to the maſſes or denſities of the particles; or it may, like magnetiſm, be dependent more on the peculiar qualities of thoſe particles than on their maſſes. If the former were the caſe, we might ſimplify our deductions by admitting that coheſion and elective attraction are the ſame thing. It will be eaſy to examine whether this poſition will, in any one inſtance, lead us into an error; and, if it does, it muſt be abandoned. Spirit of wine diſſolves reſin; water does not: hence it will follow, if the attraction depend on the denſity of particles,

Queſtion.

Elective attraction does not depend on denſity.

ticles, that the particles of ſpirit of wine are denſer than thoſe of water. But, again, water diſſolves gums; ſpirit does not: whence, by the ſame reaſoning, we ſhould deduce, that the particles of water are denſeſt. But the true inference is, that if theſe different effects depend on any general law, it does not follow the denſity of the particles; and till that general law is diſcovered, we ought to conſider the various attractions which occur in chemiſtry, as peculiar to the bodies in which they are obſerved.

—probably on figure.

Bergman, Morveau, and other eminent chemiſts, are inclined to the opinion that there is but one general power of attraction in nature, which is modified chiefly by the figure of particles when extremely near each other. But this has not been ſtrictly examined.

Aggregation.

The adheſion of parts of the ſame kind, is called aggregation. Thus, a number of pieces of brimſtone united by fuſion, form an aggregate. The union of bodies of different kinds, in a groſs way, is called mixture. Thus ſand and ſalt of tartar may be mixed together. But when the very minute parts of one body unite with thoſe of another ſo intimately as to form a body which has properties different from thoſe of either of them, the union is called combination, or compoſition. For example, ſand and ſalt of tartar, expoſed to a ſtrong heat, combine, and form a compound called glaſs. The minuteſt parts into which an aggregate can be imagined to be divided without decompoſition, are called integrant parts; but the parts into which it is divided by decompoſition, are called component parts or principles.

Mixture.

Combination, or compoſition.

Integrant and component parts.

Principles

Elements, or firſt principles.

Principles which cannot be ſubdivided by art, are called elements, or firſt principles; and the principles made up of theſe, are called ſecondary principles. Some writers carry this order ſtill farther; but it muſt be confeſſed that no means have yet been deviſed to ſhew unequivocally whether any ſuch ſubordination of principles exiſts. We may indeed diſcover the component parts of bodies; but we know nothing of their arrangement.

Heat.

See pag. 2, 3.

As the chemical attractions, like other powers of the ſame kind, are weaker, the greater the diſtance between the parts which act on each other; and as heat enlarges the dimenſions of the bodies; doubtleſs, by ſeparating their parts, it will not be difficult to explain the effect of heat upon the changes produced in bodies by their elective attractions.

Simple combination.

If two ſolid bodies, diſpoſed to combine together, be brought into contact with each other, the particles that touch will combine, and form a compound; and the proceſs will go no further, if the compound ſtill retain the ſolid form. But if the compound be of ſuch a nature as to have its point of congelation or ſolidity much lower than the temperature in which the experiment is made, or if it attract water from the atmoſphere, it will be fluid; and the eſſential property of a fluid being, that all its particles may freely move amongſt each other, the parts of each body will be at liberty to move in ſucceſſion, ſo as beſt to obey the elective attraction. The conſequence will be, that a new compound, in a fluid form, will be produced by the union of the two bodies. An inſtance of this has already been ſhewn in the mixture of ice and ſalt.

Page 19.

Suſpenſion.

If one of the two bodies be fluid at the temperature

of

Solvent, or menſtruum.

of the experiment, its parts will ſucceſſively unite with the parts of the ſolid, which will by that means be ſuſpended in the fluid, and diſappear. Such a fluid is called a ſolvent, or menſtruum, and the ſolid body is ſaid to be diſſolved. Thus water diſſolves ſalt, mercury diſſolves gold, glaſs of lead diſſolves ſand, &c.

Water.

Cauſe of error in eſtimating the attractions.

In the humid way, where the fluid ſtate is produced by means of water, and in many caſes of which the diſſolved bodies may be recovered by evaporating the water, it is uſual to attend only to the actions of the ſuſpended bodies, and neglect the fluid, becauſe common to all experiments of this kind. But as the water certainly has as great a ſhare in modifying the effect which follows, as any other of the bodies preſent, the elective attractions between bodies held in ſolution in water, will not in general be the ſame as when the menſtruum is ſpirit, oil, or æther; or when, in the dry way, one of the bodies is rendered fluid by ſtrong heat.

Limits of ſaturation:

— in fluids:

Some ſubſtances unite in all proportions. Such, for example, are acids in general, and ſome other ſalts, with water; and many of the metals with each other. But there are likewiſe many ſubſtances which cannot be diſſolved in a fluid, at a ſettled temperature, in any quantity beyond a certain proportion. Thus water will diſſolve only about one fourth of its weight of common ſalt; and if more be added, it will remain ſolid. A fluid which holds in ſolution as much of any ſubſtance as it can diſſolve, is ſaid to be ſaturated with it. But ſaturation with one ſubſtance does not deprive the fluid of its power of acting on and diſſolving ſome other bodies, but in many caſes increaſes that power. For example, water, ſaturated with ſalt, will diſſolve ſugar; and water, ſaturated with fixed air, will diſſolve iron, though, without that addition, its action on that metal is ſcarcely perceptible. The word ſaturation is likewiſe uſed in another ſenſe by chemiſts: the union of two principles produces a body whoſe properties are different from thoſe of its component parts, but which reſemble thoſe of the predominating principle. When the principles are in ſuch proportion as that neither may predominate, they are ſaid to be ſaturated with each other; but if otherwiſe, the moſt predominant principle is ſaid to be under-ſaturated, and the other over-ſaturated.

—in general.

Solution aſſiſted by heat.

Fluids in general diſſolve a greater quantity of any ſubſtance the higher the temperature. This probably ariſes from the fluidity of the body in ſolution being promoted by the heat.

Medium of combination.

When two bodies, which would not otherwiſe combine, are made to unite by the addition of a third, the latter is called a medium. Thus the iron and water, in the inſtance lately mentioned, are ſaid to have combined by the medium of fixed air.

Separation, or precipitation.

It often happens, on the contrary, that the tendency to combination between a ſolvent and another body, is weakened or deſtroyed by the addition of a third. Thus ſpirit of wine weakens the action of water upon moſt ſalts, and of courſe ſeparates them from it. If to a ſaturated ſolution of nitre in water there be added an equal meaſure of ſtrong ardent ſpirit, the nitre becomes ſolid, and falls down in an inſtant to the bottom of the phial. The ſubſtance thrown down from a ſolvent by the addition of any other matter, is ſaid to

be

CHEMICAL ATTRACTIONS.

be precipitated, and many ſuch products are called precipitates.

Simple elective attraction.

When a compound of two principles is ſo affected by the addition of a third, that a new compound is formed of this laſt principle and one of the other two; at the ſame time that the principle which was part of the original compound, but does not enter into the ſecond combination, is diſengaged; the decompoſition and new combination are ſaid to be produced by ſimple elective attraction or affinity.

Examples of ſimple elective attraction:

— in the humid way:

Moſt operations of nature or art are ſo complex, that it is exceedingly difficult to exemplify theſe effects. The following inſtance will exhibit an effect of ſimple elective attraction, if we overlook the effect of the water, which is preſent in both ſalts. Common ſalt conſiſts of two principles. The one is the mineral alkali commonly known by the name of ſalt of ſoda; and the other is the marine acid, which, when combined with water, is known by the name of ſpirit of ſalt. If the vitriolic acid be poured upon common ſalt, it will attract the alkali more ſtrongly than it is attracted by the marine acid. The conſequence will be, that it will unite with the alkali, and form a new compound, called Glauber's ſalt, while the marine acid flies off in the form of air. This air, meeting with moiſture in the atmoſphere, combines with it, and forms the common marine acid viſible in the form of white fumes.

— in the dry way.

In the dry way, if a combination of lead and ſulphur be fuſed with iron, the ſulphur unites with this laſt, and leaves the lead free.

If we were to ſpeculate on theſe events, it would be eaſy to ſhew from what ſuppoſed action among the particles they may happen. If a particle of alkali be ſurrounded by particles of marine acid, and the vitriolic acid be added, the particles of theſe laſt may be ſo ſtrongly attracted by the alkali as to approach it, and remove the particles of marine acid beyond the limit of ſenſible attraction. This effect may be facilitated by the action of heat, which increaſes the diſtances between parts of bodies; and the diſengaged ſubſtance may aſſume either the ſolid, fluid, vaporous, or aerial ſtate, according to the temperature and the peculiar properties of the body itſelf in that reſpect.

Double elective attraction.

Where two bodies, each conſiſting of two principles, are ſo diſpoſed as to act on each other, and the order of the principles changes in ſuch a manner as to form two other bodies compoſed of different principles, the change is ſaid to be produced by double affinity, or double elective attraction.

Example: in the humid way:

In the humid way: Let mercury be diſſolved in the nitrous acid (or ſpirit of nitre of the ſhops) until the acid will take up no more. The ſolution will then conſiſt of a mercurial ſalt diſſolved in water. Let tartar, which is a ſalt conſiſting of a peculiar acid united with the vegetable alkali, be added. The conſequence will be, that the alkali of the tartar will quit its own acid, and, uniting with the nitrous acid, will form nitre, which will continue diſſolved; and, on the other hand, the acid of the tartar, being diſengaged, will unite itſelf to the mercury, and form a ſalt, which, on account of its inſolubility, will fall down in the form of a powder.

— dry way.

In the dry way: If an alloy of gold and copper be fuſed with the antimony of the ſhops, which conſiſts of ſulphur and a metallic body called regulus of antimony, the ſulphur will unite with the copper, and float above, while the gold and the regulus combine together, and occupy the lower part of the crucible.

Numerical expreſſion of affinity.

One of the principal objects of chemical reſearch conſiſts in the numerical expreſſion of the attractive powers of bodies. If this were well aſcertained, it is probable we ſhould be able to foretel, not only the effects of ſimple or double affinity, but likewiſe in what caſes the compounds of three or more ſubſtances take place. See Appendix.

Mechanical properties of bodies do not follow the properties of their component parts.

No regular connection has been yet diſcovered between the ſolubility in water, the fuſibility, volatility, ſpecific gravity, and other obvious properties of the component parts of bodies, and of the compounds they produce. Hence it happens, in humid operations, that the inſoluble products will either fall to the bottom, or riſe to the ſurface, according to their weights. In ſome proceſſes, all the products will be thus ſeparated; and in others the whole will remain diſſolved. In the dry way likewiſe ſome products will riſe, others will become fluid, and others fixed, ſo as to require a ſtronger heat to fuſe them than before.

Utility of theſe changes.

Theſe ſeveral changes afford means to the chemiſt of ſeparating bodies from each other. When two different kinds of ſalt are diſſolved in water, it would be almoſt impoſſible to ſeparate them if they were both equally ſoluble; becauſe evaporation would leave both in a confuſed maſs. But where the one is more ſoluble than the other, the latter will begin to be ſeparated, and may be taken out at a period of the evaporation, at which the whole of the former will remain ſuſpended. So likewiſe the advantages derived from the proceſſes of diſtillation, ſublimation, and other dry operations, are founded on theſe different properties of bodies.

Cryſtallization.

The parts of all bodies which take the ſolid ſtate are diſpoſed to arrange themſelves in ſuch a manner as to produce ſome regular geometrical figure in the ſolid. Thus ice, during its formation in water, or even in the open air, always aſſumes a regular figure, as far as circumſtances will permit. The ſame is obſervable in the fixation of other fluids, and alſo in the ſeparation of bodies from their ſolvents, as ſalts from water. This property is called cryſtallization, and the regularly-figured bodies are called cryſtals. The figure of cryſtals is influenced by ſo many circumſtances—ſuch as the quickneſs of their formation, the temperature and agitation of the fluid, the preſence of light, and others—that little dependence can be placed on it as an indication of the compoſition of bodies; though the experienced operator will doubtleſs derive ſome advantage by attending to it.

Polarity of the particles of bodies.

The regular arrangement of parts in cryſtallization is ſuppoſed by ſome to be the conſequence of a property in the particles of bodies, ſimilar to polarity in magnetiſm. And indeed it ſeems reaſonable to infer, that two compounded particles, coming together by attraction, undiſturbed by any other cauſe, ſhould diſpoſe themſelves ſo as to apply ſuch ſides of each together, as are occupied by principles the moſt attractive of each other.

BOOK II.

PARTICULAR CHEMISTRY.

SECTION I.

OF THE GENERAL PRINCIPLES OF BODIES.

CHAP. I.

CONCERNING THE GENERAL DIVISION OF CHEMICAL PRINCIPLES.

PRINCIPLES OF BODIES.

Arrangement.

AMONG the various diviſions or arrangements of chemical principles, that which follows their reſpective degrees of ſimplicity muſt undoubtedly prove the moſt uſeful, becauſe the more compounded bodies will eaſily aſſume a regular order when their reſpective principles are known and properly claſſed. There is however a limit in the advantages that may be derived even from this method of diviſion. The more we ſucceed in ſimplifying the principles of bodies, the more difficult it is to determine truly what paſſes in

PRINCIPLES OF BODIES.

Arrangement.

chemical operations; becauſe theſe principles, when in their moſt diſtinct ſtate, have the aerial form, and cannot therefore be managed or weighed without conſiderable difficulty. From this cauſe it is that, while we have no diſputes concerning the changes of combination in groſſer and leſs ſimple ſubſtances, the moſt eminent chemiſts often differ in their opinions concerning the tranſitions of firſt principles from one combination to another; and are not agreed concerning the exiſtence of ſome of them. The peculiar properties of bodies may be changed, either by the addition or ſubtraction of ſome of their component parts; and it is eaſy to form a notion that ſuch a change may alſo happen by a mere alteration in the diſpoſition or relative arrangements of their parts, without any change in their quantities. To determine which of theſe events takes place, when we behold only the conſequent change, is ſometimes impracticable, for want of a ſufficient number of facts; and in moſt caſes the complete inveſtigation requires the unprejudiced and patient exertion of all the powers of the mind. It will be proper therefore, in an elementary arrangement, to fix our attention chiefly on the moſt palpable component parts of bodies, which are ſufficiently ſimple; and where they are not the ſimpleſt, to ſpeak of their principles in the analytical method.

Enumeration.

The component parts of bodies are either,

1. Principles whoſe exiſtence is doubtful: theſe are heat, light, and phlogiſton.

2. Principles which have not been exhibited in a ſolid or fluid ſtate, or diſſolved in water, in any notable

proportion: theſe are vital air, phlogiſticated air, and inflammable air.

Enumeration.

3. Water.
4. Earths.
5. Alkalis.
6. Acids.
7. Metals.
8. Mineral combuſtibles.
9. Parts of organized ſubſtances, whether obtained by mechanical preſſure, by ſimple ſolution in water or ardent ſpirit, by a gentle or a ſtrong heat, by the action of ſolvents, or by ſpontaneous decompoſition.

Animal, vegetable, and mineral kingdoms.

The only general diviſion of bodies at preſent referred to in the writings of modern chemiſts, is that by which they are claſſed into three kingdoms, called the animal, vegetable, and mineral kingdoms. The kind of bodies arranged in the two firſt kingdoms is obvious from the terms; and all other bodies are conſidered as belonging to the mineral kingdom.

Salts.

Alkalis, acids, and ſuch compounds as they enter into, are diſtinguiſhed generally by the name of ſalts. The leading character of ſalts is a ſtrong tendency to combination, there being no bodies in nature which are not acted upon by ſome ſaline ſubſtance. This tendency appears in their eminent degree of ſolubility in water. All bodies known only by the name of ſalts, are ſoluble in leſs than two hundred times their weight of boiling water. The ſame cauſe produces their ſapidity, or taſte, which was regarded by the earlier chemiſts as a diſtinctive character of ſalts.

Metals are ſometimes claſſed with combuſtible bodies; and, ſtrictly ſpeaking, they are combuſtible. But

as

PRINCIPLES OF BODIES.
Metals.

as none of them poſſeſs this property in ſuch a degree as to burn away in the common air, without the co-operation of other inflammable bodies, which are neceſſary to maintain their high temperature; and as they poſſeſs other remarkable properties peculiar to themſelves—they require to be placed in a ſeparate claſs.

CHAP. II.

CONCERNING HEAT, LIGHT, AND PHLOGISTON, CONSIDERED AS COMPONENT PARTS OF BODIES.

DOUBTFUL PRINCIPLES.

Heat. Page 6. 21.

Light.

Newton's Optics, ſub fine.

IT has already been ſtated, that the exiſtence of heat, as a peculiar ſubſtance, is not proved; and, among philoſophers of the firſt eminence, there are ſeveral who think the opinion that it is a mere modification, is the moſt probable. With regard to light, the opinions of the world are leſs divided. It is generally taken for granted that light is a ſubſtance, or an emanation of particles of prodigious minuteneſs, which are projected in right lines, with extreme velocity, from luminous bodies; and that they are repelled from all bodies at certain diſtances, and at leſs diſtances attracted, ſo as to produce all the effects of reflection, refraction, and inflection, in the rays they compoſe. Theſe particles are ſuppoſed to be either of various magnitudes, or differently acted on by other bodies, and from that cauſe to be ſeparable from each other; in which ſeparate ſtate they affect the organ of ſight with the ſenſation of various colours.

Subtle fluid.

Many philoſophical writers have conſidered it as an axiom, that a body cannot act where it is not[*]; and have

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[*] It may be obſerved that this poſition is very doubtful. All our knowledge is derived from an obſervation of the actions which take place between bodies. Now we never ſee bodies act where

DOUBTFUL PRINCIPLES.

have thence inferred, that the univerſe is occupied by a ſubtle fluid, whoſe action cauſes bodies to approach and recede from each other in the phenomena of attraction and repulſion. Light is conſidered by ſome authors * as a modification of this fluid, in the ſame manner as ſound is admitted to conſiſt in an undulatory motion of the air, communicated from ſonorous bodies. We ſhall not here examine the merits of this queſtion, but ſhall only obſerve, that no deciſive experiments have yet been offered in ſupport of either opinion.

Light.

Burning lens, or mirror.

When a great number of rays of light are made, either by a burning glaſs or concave ſpeculum, to paſs through a ſmall ſpace, they excite a moſt powerful heat in bodies placed in the focus. The ſtrongeſt heat yet known is of this kind. The heat produced in bodies by the action of light, is in general greater, the more light is cauſed to diſappear. Bodies which either tranſmit or reflect the light in large quantities, are very little heated by the focus of a burning apparatus. Similar coatings of black paint, the one upon a plate of iron, and the other upon a plate of paſteboard, being expoſed in circumſtances perfectly ſimilar to the ſun's rays, the heat produced was greater in the iron, though the maſs

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where they are, but always where they are not. In attraction and repulſion this is evident; and in impulſe, there are the beſt reaſons to conclude that the impelling body approaches within a certain diſtance of the impelled body, and then acts by its repulſive force without contact. Even the particles of bodies do not touch; for, if they did, how could a diminution of temperature bring them nearer together? Of the penetrability of matter we need not ſpeak in this place.

* Of theſe the great Euler ſtands firſt. See his Letters to a German Princeſs.

of

DOUBTFUL PRINCIPLES.

of this laſt was near ten times that of the paſteboard[*]. It has been often aſſerted, that heat and light are the ſame thing. But the light of a fire will paſs through a pane of glaſs, and the heat will remain behind, as is moſt evidently ſhewn by interpoſing the glaſs between the fire and a concave metallic mirror[†]. The focus of the mirror, though as luminous as before, will produce no heat. A bright table-ſpoon may be uſed where a mirror is not at hand. The preſence of light has a conſiderable effect upon the proceſs of cryſtallization; and in many inſtances it produces a change in bodies of an oppoſite nature to that which they ſuffer from combuſtion.

Light and heat differ.

Phlogiſton.

During the combuſtion of inflammable bodies, we perceive a continual eſcape of volatile matter; and as the fixed reſidue is uſually found to be much leſs than the original weight of the body which has been burned, it was natural for the earlier chemiſts, who were unacquainted with the nature and quantity of the volatile products, to infer that combuſtion conſiſted in the eſcape of ſome principle which inflammable bodies poſſeſſed, but which was wanting in ſuch as could not be burned. This doctrine has been occaſionally modified till our time; and the experiments made by expoſing to heat a metal that had been burned, together with another more inflammable body, in a cloſed veſſel, in which the latter was conſumed, while the former recovered its inflammability, were, till lately, received as undoubted proofs that the principle of inflammability or phlogiſton had

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[*] Dr. George Fordyce, in Phil. Tranſ. Vol. LXXVII. p. 313.

[†] Scheele on Air and Fire, p. 70. Engliſh tranſlation.

DOUBTFUL PRINCIPLES. Phlogiſton.

had paſſed from the one body to the other. It was indeed urged as an objection, that metallic bodies, ſo far from loſing weight by calcination, do really become heavier: and later experiments ſhewed that this increaſe of weight was gained from the air; the abſolute neceſſity of whoſe preſence in combuſtion had been formerly either overlooked, or ſlightly regarded. But this was explained from the doctrine of affinity, by the ſuppoſition that the pure air of the atmoſphere, combining with the baſe of the combuſtible body, ſet its phlogiſton, or fire, at liberty. The modern doctrine of heat however appears to ſhew, that the increaſe of temperature ariſes from the air, and not from the combuſtible body; and this conſideration has led ſeveral eminent French chemiſts to reject phlogiſton altogether*, and to conſider the proceſs of combuſtion as nothing elſe but the act of combination of vital air with the combuſtible body; the matter of heat, which according to them is combined with the air, being ſet at liberty. Page 33.

Among the chemiſts who maintained the old opinion it became therefore an object of enquiry, whether the air abſorbed in combuſtion really either expels, or combines with, any principle common to all inflammable bodies. For if this ſhould be reſolved in the affirmative, the ſubſtance found would be the

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* This doctrine may be ſeen diſplayed at length in the notes annexed to Kirwan's Eſſay on Phlogiſton, ſecond edition. M. Lavoiſier is the firſt of the chemiſts who explained and illuſtrated the new doctrine by a ſet of accurate experiments, and a judicious arrangement of the known facts; but M. Bayen may be conſidered as the firſt modern who, upon rational grounds, rejected the phlogiſton. The excellent John Mayow is the father of this doctrine.

DOUBTFUL PRINCIPLES.

Phlogiſton.

principle of inflammability or phlogiſton. The evident way to determine this muſt be, to heat combuſtible bodies in cloſed veſſels. The moſt predominant volatile product is, in theſe caſes, found to be a very light aerial matter, which is very inflammable when common air is preſent; and is known by the name of inflammable air. Mr. Kirwan firſt announced this as the phlogiſton.

Queſtion.

The great queſtion now is, whether inflammable air be contained in all combuſtible bodies, ſince they do not all emit it by mere heat; and it is evident that, if combuſtion can be effected without it in any one inſtance, it cannot be the indiſpenſable and univerſal principle of inflammability. Its exiſtence is denied in ſulphur, phoſphorus, charcoal, metals, and ſome other ſubſtances. It may however be obtained by heating theſe, if water be preſent: whether it is afforded by the ſubſtance under examination, or by the water, is therefore the ſubject of controverſy.

We may reſume this ſubject as we advance; but enough has been ſaid in this chapter to ſhew the learner that the exiſtence of heat, light, and phlogiſton, as chemical principles of bodies, is not yet incontrovertibly eſtabliſhed.

CHAP.

CHAP. III.

OF PHLOGISTICATED, DEPHLOGISTICATED OR VITAL, AND INFLAMMABLE AIR, AND OF THE COMPOSITION AND GENERAL PROPERTIES OF WATER.

COMBUSTION.

Page 50.

Effects of combuſtion on common air.

WHENEVER combuſtion, or an equivalent proceſs, is carried on in a veſſel containing atmoſpherical air, which is incloſed either by inverting the veſſel over mercury, or by ſtopping its aperture in a proper manner, it is found that the proceſs ceaſes after a certain time; and that the remaining air, which is about three-fourths of the whole bulk, is of ſuch a nature, as to be incapable of maintaining combuſtion, or ſupporting the life of animals. From this experiment it is clear that one of the following deductions muſt be true: 1. The combuſtible body has emitted ſome principle which, by combining with the air, has rendered it unfit for the purpoſe of combuſtion: Or, 2. It has abſorbed part of the air, which was fit for that purpoſe, and has left a reſidue which is of a different nature: Or, 3. Both events have happened; namely, that the pure part of the air has been abſorbed, and a principle has been emitted which has changed the original properties of the remainder.

Obſervations.

The facts muſt clear up theſe theories. The firſt cannot be altogether true, becauſe the reſidual air is not only of leſs bulk, but of leſs ſpecific gravity, and the burned body is heavier than before. The air cannot therefore have received ſo much as it has loſt. The ſecond is the doctrine of the philoſophers who deny the exiſtence of phlogiſton, or a principle of inflammability. And the third muſt be adopted by thoſe who maintain that ſuch a principle eſcapes from bodies during combuſtion. This reſidue was called phlogiſticated air, in conſequence of ſuch an opinion.

Opinions.

In the opinion that inflammable air is the phlogiſton, it is not neceſſary to reject the ſecond deduction. For the pure or vital part of the air may unite with inflammable air, ſuppoſed to be in a fixed ſtate in the combuſtible body; and if the product of this union remain fixed, it is plain that the reſidue of the air after combuſtion will be the ſame as it would have been if the vital part had been abſorbed by any other fixed body. Or if the vital air be abſorbed while the inflammable air is diſengaged, and unites with the aerial reſidue, this reſidue will not be heavier than before, unleſs the inflammable air it has gained exceeds in weight the vital air it has loſt.

Phlogiſton.

It is rendered more probable that the air of the atmoſphere conſiſts of a mixture of a vital and a noxious part, by the fact, that, when fixed bodies have been burned or calcined (for example, mercury converted into precipitate per ſe), the vital air may be again extricated from ſome of them. This is found to maintain combuſtion in the moſt effectual manner, and is almoſt totally abſorbed in that proceſs, inſtead of leaving a reſidue ſuppoſed to be changed by phlogiſtication. And, on the other hand, there is no unequivocal proof that vital air can be obtained from the phlogiſticated part by any operation whatever.

Compoſition of the atmoſphere.

VITAL AIR.

Subſtances which afford vital air.

Vital air may be obtained by heat from nitre, from alum, from mercury calcined without addition, and uſually called precipitate per ſe; from red precipitate, from minium, from manganeſe, and from lapis calaminaris. Moſt nitrous and vitriolic ſalts afford it by heat. It is contained in the bladders of ſea-weed, and in waters. The green vegetable matter formed in water emits it when expoſed to the ſun's light; and it is found in general that the leaves of plants, in like circumſtances, emit vital air. Whence it appears that there are abundant proviſions for reſtoring the purity of the air, which is continually injured by combuſtion, reſpiration, fermentation, and other proceſſes.

Reſpiration is a proceſs of the ſame kind as combuſtion.

The reſpiration of animals produces the ſame effect on air as combuſtion does; and their conſtant heat appears to be an effect of the ſame nature. When an animal is included in a limited quantity of atmoſpherical air, it dies as ſoon as the air is vitiated. Vital air, in like circumſtances, maintains the life of animals much longer than common air.

Vegetables affect the air.

Vegetables do not thrive in vital air. Theſe appear to render common air purer, by abſorbing its phlogiſticated or noxious part. They emit vital air when the ſun ſhines on them. This is ſuppoſed to ariſe from the decompoſition of water.

Nitrous air uſed as a teſt.

Several of the metals, and other combuſtible ſubſtances, when diſſolved in ſpirit of nitre, afford or extricate, by an effervеſcence, a kind of air called nitrous air, of which we ſhall more particularly ſpeak in its place. Mercury is one of theſe metals. If this air be mixed with any other air in which vital air is contained, it unites with this laſt, and forms red fumes, which fall down, and are found to conſiſt of nitrous acid. The air itſelf is diminiſhed in bulk by the loſs; and hence the nitrous air becomes a teſt of the goodneſs of reſpirable air. For the diminution is greater the greater the quantity of vital air.

Subſtances which afford inflammable air.

All animal or vegetable ſubſtances which can be burned in the open air, charcoal excepted, will afford inflammable air, if heated in cloſed veſſels. This is uſually mixed with air of other kinds, and with oleaginous matter. Charcoal and ſeveral metals afford inflammable air by heat, if water be preſent. Some metallic ſubſtances, during their ſolution in acids, afford or extricate inflammable air, which is of the pureſt kind. This fluid is very light, according to its purity. It is uſually about ten times as light as an equal bulk of common air; but it is ſaid to have been obtained ſeventeen times lighter [*]. The common proceſs for obtaining it is, to diſſolve iron filings or ſhavings in diluted vitriolic acid.

Water produced by combuſtion of vital and inflammable air.

If a mixture of about two parts, by meaſure, of inflammable air, with one of vital air, be ſet on fire, in a ſtrong cloſed veſſel, which may be done by the electric ſpark, the airs, if pure, will almoſt totally diſappear, and the product will be water and an acid. Till lately, the produce was thought to be mere water; and ſeveral eminent chemiſts at Paris have ſtrongly inſiſted that it was equal in weight to the two airs made uſe of. This agreement however has never been proved [†]; and, as every kind of air uſually

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By Morveau. See the Aeroſtat de Dijon.

[†] When we conſider the great bulk and ſmall weight of air, the magnitude of the apparatus, and the imperfection of the beſt balances,

Whether water be a compound.

uſually holds a large proportion of water in ſolution, from which the aqueous product might be derived, it ſtill remains a problem to be decided, whether water, with reſpect to the preſent ſtate of our knowledge, be a ſimple or a compound ſubſtance. For the water may either be formed by the union of the two airs, or the real airs may be totally employed in forming the acid, while the water is ſimply condenſed upon their loſing the aerial form.

The extenſive utility of water:

Water is a ſubſtance which enters into ſo many operations of nature and art, that a full deſcription of its properties would include moſt of the properties of other bodies. Its weight is uſed as the meaſure of ſpecific gravity; its capacity for heat is aſſumed as the ſtandard of compariſon for other bodies; its temperature at the changes from ſolidity to fluidity and to the elaſtic ſtate, are taken as the fixed points for thermometers; and, in a word, the ſolubility of bodies denotes, in general, the action which this ſubſtance exerts upon them.

—its general properties.

Water being uſually met with in theſe climates in the fluid ſtate, its properties are in moſt caſes treated of under that form. If it be heated it gradually expands, and is converted into vapour at 212° of Fahrenheit, with ſuch rapidity as to counteract the effect of heat in raiſing its temperature. In a ſtrong cloſed metallic veſſel it may be heated nearly red hot, and in

Page 18.

balances, none of which in practice weigh beyond five places of figures (p. 67—69), we ſhall find ſufficient reaſons to queſtion the accuracy of concluſions, which ſuppoſe the quantities of air and water to be rigorouſly aſcertained. Theſe reaſons are ſtill more enforced by the conſideration, that the experiments of Dr. Prieſtley and M. Lavoiſier do not agree.

this

this ſtate its ſolvent powers are greatly increaſed. If the veſſel be opened, ſteam ſuddenly ruſhes out, and the temperature of the fluid falls inſtantly to 212°. When water is cooled, it gradually contracts till within 8° of freezing, and then expands till it freezes. The parts of the water which firſt become ſolid by freezing, have the form of ſword-blades, croſſing each other at angles of 60 degrees. It will ſhoot out into this form in the open air, as may be ſeen in ſnow or hoar froſt upon trees. Ice is conſiderably lighter than water, and therefore floats upon it. The expanſion of ice at the time of its formation is made with ſuch force as to burſt the ſtrongeſt metallic veſſels: and the expanſion of ſteam is prodigiouſly great. This laſt power, being very manageable, by transferring greater or leſs quantities of ſteam into the veſſels of apparatus, or by condenſing it, has been applied to the moſt important mechanical uſes in the ſteam engine, and will doubtleſs be applied to many more.

General properties of water.

Ice.

When water is included in a metallic globe or veſſel, called the eolipile, which has only a very ſmall aperture, and it is then made to boil, the ſteam iſſues out very violently, and will ſtrongly urge a fire in the ſame manner as bellows. This has been thought to prove a decompoſition of the water. But it is not the ſteam which excites the fire, but the air it drives before it. For an eolopile will not produce this, but the contrary effect, unleſs a body of air be interpoſed between its aperture and the fire *.

Effects of the eolipile.

The denſity of water † is ſuch that a cubic foot

Denſity of water.

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* Lewis's Philoſophical Commerce of Arts, p. 21.

† This was found by Cotes, who ſays it is very nearly ſo. See his Hydroſtatical Lectures, p. 76, ſecond edition.

WATER.

Specific gravity of water.

weighs 1000 ounces avoirdupois weight. This fortunate concurrence of unity of meaſure with a roun number in the weight, renders the common tables ſpecific gravities very uſeful in computations. Fo the numbers will denote the avoirdupois ounces in cubic foot of each ſubſtance, provided the ſpecif gravity of water be taken to be 1000.

What waters are pureſt.

The pureſt common waters are the lighteſt, ar lather well with ſoap. For chemical purpoſes, wat ſhould be boiled on a common fire for a ſhort time, diſſipate any volatile animal or vegetable impregnati it may poſſeſs, and afterwards diſtilled to about o half. The water which comes over is very pure, a the accurate chemiſt ſhould uſe no other. On accou of the extenſive uſe and importance of diſtilled wat it is adviſable not to perform this operation but wi veſſels kept for that and no other purpoſe.

CHAP. IV.

OF THE SIMPLE OR PRIMITIVE EARTHS.

EARTHS.

CHEMISTS diſtinguiſh ſuch ſubſtances by the name of pure earth, as are brittle, incombuſtible, infuſible by the heat of furnaces, not ſoluble in ſeveral hundred times their weight of water, and deſtitute of metallic ſplendour. There are few earthy ſubſtances which may not be reduced by analyſis to one of the five following primitive earths:—the ſiliceous, argillaceous, calcareous, ponderous, and magneſian earths; or otherwiſe, taken ſubſtantively, they are called ſilex, clay, lime, barytes, and magneſia.

Five primitive earths.

The adamantine ſpar, the jargon of Ceylon, and a mineral ſubſtance from New South Wales, have afforded earthy ſubſtances which, as far as experiments have yet determined, are different from any of theſe five. But they will not materially affect the general arrangement of chemiſtry, until future reſearches ſhall have proved that they are more abundantly found than at reſent we have reaſon to ſuſpect.

New earths.

In ſome ſyſtems a diſtinction is made between earths nd ſtones; but this is of no utility in the enquiry reſpecting their component parts and properties. A ſtone is nothing more than a hard earthy maſs, and n earth in powder is an aggregate of very minute ones.

Stones.

Siliceous earth abounds in all natural bodies which re hard enough to ſtrike fire with ſteel. Of theſe,

Siliceous earth.

rock

rock cryſtal, quartz, flint, gritſtone, jaſper, and moſt of the precious ſtones or gems, are the chief ſpecimens. Like all other ſimple ſubſtances, it is never found pure in nature. The leading or principal character of this earth is, that it is not perceptibly acted upon by any acid but that of fluor ſpar. Alkalis diſſolve it in the moiſt as well as in the dry way, but moſt efficaciouſly and in all proportions in the latter. Hence the method of obtaining ſiliceous earth in a ſtate of purity conſiſts in diſſolving cryſtal or quartz in a large proportion of fixed alkali in ſtrong fuſion: for example, four parts by weight of the ſalt to one of the earth. This combination will unite with water, in which it muſt be diſſolved. The ſolution is uſually called liquor of flints. An exceſs of acid being added, will combine with the alkali, and ſuch other earths as may have exiſted in the natural ſpecimen; and the pure ſiliceous earth, being inſoluble in water, will fall to the bottom. Repeated waſhing in diſtilled water will ſeparate all the extraneous matter from theſe particles, which, when dried, conſiſt of ſiliceous earth uncombined with any other ſubſtance.

Liquor of flints.

Pure ſiliceous earth.

The particles of ſiliceous earth, thus obtained, are in a ſtate of ſuch minute diviſion, that they will remain ſuſpended for a conſiderable time in water; and this fluid, violently heated in a ſtrong cloſed veſſel, will diſſolve a portion of it. Siliceous earth is unalterable in the moſt violent heats chemiſtry can produce in a furnace. Rock cryſtal, which is the pureſt ſpecimen of this earth, of which it contains ninety-three parts in the hundred, has been fuſed by flame urged upon it by a ſtream of dephlogiſticated air from a blow-pipe. With fixed alkalis, in the proportion of about double its own weight, it forms glaſs. Calcined metals, eſpecially lead, alſo diſſolve it, and form glaſs by fuſion. The combination of this earth with fluor acid is very ſparingly ſoluble in water.

Argillaceous earth.

The principal natural ſpecimens of argillaceous earth are, clays, properly ſo called, marles, boles, ſlates or ſchiſtus, and mica. In none of theſe, except the flagſtone, does the argillaceous earth amount to ſo much as half their weight, though their predominating qualities appear to depend upon it. The moſt obvious characters of this earth are, an adheſion to the tongue, or any wet and ſoft body, in the more ſolid ſpecimens; and a remarkable tenacity, ductility, or kneadability ſerve to diſtinguiſh moiſtened clays in a moſt eminent degree. It is ſoluble in acids, but alkalis act much leſs upon it, either in the dry or moiſt way, than they do on ſiliceous earth. Alum is a combination of argillaceous earth with vitriolic acid. If the concrete volatile alkali be added to a ſolution of pure alum, the alkali and acid unite, while the clay falls to the bottom, united only with a ſmall quantity of fixed air. The fluid muſt be abſtracted by decantation, and the precipitate waſhed with diſtilled water, and dried.

Earth of alum.

Common clays.

Clays may be eaſily diffuſed and ſuſpended in water, but are not ſoluble in any ſenſible degree. The ſudden application of ſtrong heat hardens their external parts, which afterwards burſt by the exploſion of the moiſture within. By a more gradual heat, pure clay contracts very much, becomes hard and full of cracks or fiſſures. The preſence of ſiliceous earth in common clays,

EARTHS.

clays, where it uſually conſtitutes above half the weight, renders the contraction more uniform throughout, and prevents the cracks, probably in no other way than by rendering them more numerous, and too ſmall to be perceived. When thus baked, it conſtitutes all the varieties of bricks, pottery, and porcelain. Theſe, if baked in a ſtrong heat, give fire with ſteel; a property that may be attributed to the ſiliceous earth they contain, which cannot act on the ſteel unleſs firmly ſet in the hardened clay. The dimenſions of pottery are leſs, the greater the heat to which the article has been ſubjected. On this property is conſtructed a thermometer for meaſuring the heat of furnaces, by igniting a ſmall brick of known dimenſions therein, and afterwards meaſuring its contraction*. Baked clay is no longer kneadable with water, though as finely pulverized as mechanical means can go. Hence it has been inferred that clays owe their ductility to a kind of gluten which is ſuppoſed to be diſſipated by heat. They recover that property however by ſolution in an acid and precipitation; whence it ſhould ſeem to depend either on a minute portion of acid contained in clays, or the ſmallneſs of the particles when precipitated.

Pottery.

Thermometer for ſtrong heat.

Calcareous earth:

Calcareous earth, or lime, predominates in moſt ſtones which are ſoft enough to be ſcratched with a knife. Theſe are chalk, limeſtone, marble, ſpars, gypſum, or plaſter ſtone, and various others. As the lime is moſt frequently combined with fixed air, it is uſual for mineraliſts to drop a ſmall quantity of nitrous acid upon the ſtones they are deſirous of claſſing; and if it froths by the eſcape of the fixed air, they conclude that lime enters into the compoſition. To obtain pure calcareous earth, powdered chalk muſt be repeatedly boiled in water, which will deprive it of the ſaline impurities it frequently contains. It muſt then be diſſolved in diſtilled vinegar, and precipitated by the addition of concrete volatile alkali. The precipitate, when well waſhed and dried, will conſiſt of lime united to fixed air; the latter of which may be driven off by heat, if neceſſary.

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* See Wedgwood in Phil. Tranſ. Vol. LXXII. and LXXIV.

Method of obtaining it pure.

Lime, or quicklime.

If chalk, marble, limeſtone, ſpar, or any other ſpecimens of this earth, containing fixed air, be expoſed to continued ignition, they give out fixed air and water, to the amount of near half their weight. The remainder, conſiſting chiefly of lime, has a ſtrong tendency to combination, and attracts water very powerfully. The addition of water to lime produces a very conſiderable heat, attended with noiſe, and agitation of the parts, which break aſunder; and a phoſphoric light is ſeen if the experiment be made in the dark. Lime thus ſaturated with water, is ſaid to be ſlaked. Water diſſolves about one ſeven hundredth part of its weight of lime, and is then called lime-water. This ſolution has an acrid taſte, and turns ſyrup of violets to a green colour. If lime-water be expoſed to the open air, the lime attracts fixed air, and is by that means converted into chalk; which, not being ſoluble in water, forms a cruſt on the ſurface, formerly called cream of lime, that, when of a certain thickneſs, breaks and falls to the bottom: and in this way the whole of the lime will in time be ſeparated.

Slaked lime.

EARTHS.

Mortar.

The paſte of lime and water, called mortar, has a degree of adheſion and ductility, though much leſs than clay. When dry, it is friable like chalk. A mixture of ſand, or broken earthen veſſels, greatly increaſes its firmneſs, which it ſeems to effect by rendering it more difficult for the parts to be removed with reſpect to each other. When mortar is left to dry by the gradual evaporation of its ſuperfluous water, it is very long before it obtains its utmoſt degree of firmneſs. But if dry quick-lime be mixed with mortar, it gradually abſorbs the ſuperfluous water, and the maſs becomes ſolid in a very ſhort time.

Gypſum, or plaſter of Paris.

Gypſum, or plaſter of Paris, conſiſts of lime united to the vitriolic acid, together with water. If this ſubſtance be expoſed to a moderate heat, part of the water is driven off. The dry powder which remains may be mixed with water to the conſiſtence of thin paſte, and poured into a mould; and ſoon afterwards it ſuddenly becomes ſolid, at the ſame time that it is a little heated, and its bulk ſomewhat increaſed. This effect may be explained by obſerving that the particles of the gypſum are at firſt ſimply wetted by the water, in the ſame manner as happens with clay; and for that reaſon no other effect takes place, than the production of an imperfect degree of fluidity, from the motion of the parts among each other being facilitated: but when the water, by the gradual progreſs of the action between it and the dried gypſum, becomes combined in the ſame manner as before the calcination, it is abſorbed, and enters into the compoſition of a ſolid body; the imperfect fluidity, ariſing from the preſence of uncombined water, diſappears; heat is developed, and the whole maſs takes the ſolid form. The uſe of this material for caſting ſmall ſtatues, medallions, and other ornaments, is well known.

Animal earth.

The earth which enters into the compoſition of the bones of animals and ſhells of fiſh is calcareous. In the former it is united with the phoſphoric acid, and in the latter with fixed air.

Ponderous earth.

Ponderous ſpar, or marmor metallicum.

Ponderous earth, or barytes, is not found very abundantly, or in large continued maſſes, but chiefly in the vicinity of mines, or veins of metal. Its ſpecimens are either aërated ponderous ſpar, which has been found at Alſton Moor, in Cumberland *, and conſiderably reſembles alum, but is of a ſtriated texture: or vitriolated ponderous earth, either in the form of a tranſparent ſpar or an opake earth; of a white, grey, or fawn colour; frequently of no regular figure, but often in the peculiar figure of a number of ſmall convex lenſes, ſet edgwiſe in a ground. The opake ſpecimens have been called marmor metallicum, on account of their great weight; but the Engliſh miners call it cawk. Moſt ſpecimens of this earth are above four times the weight of an equal bulk of water, which conſtitutes an obvious difference between this and calcareous earth, which is little more than twice that weight: they are

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* Analyſed by Dr. Withering. See Phil. Tranſ. Vol. LXXIV. Mr Watt, jun. in the third volume of the Mancheſter Memoirs, gives reaſons for concluding that this ſpecimen came from the lead mine of Anglezark, near Chorley, in Lancaſhire, where it is plentifully found. He obſerves that this is the only mine in England which is known to afford it. It has alſo been found in the mines of Stontain and Dunglaſs, near Dumbarton, in Scotland.

ſcarcely,

EARTHS.

ſcarcely, if at all, ſoluble in water. The liver ſtone, or lapis hepaticus, contains about one third part of this earth. If ponderous ſpar be fuſed with about twice its weight of fixed alkali, its acid will unite with this laſt, and form a ſalt, which may be waſhed off by water, the ponderous earth remaining behind in combination with fixed air. This may be deprived of its fixed air by a ſtrong heat, which converts it into a ſtate perfectly reſembling quick-lime in taſte, and exhibiting ſimilar phenomena with water.

To obtain pure ponderous earth.

Native aerated ponderous earth.

The natural aërated ponderous earth differs from that produced by art, in the circumſtance that it contains no water; and to this it ſeems to be owing that it does not loſe its fixed air by mere heat.

This earth differs from lime.

Though this earth reſembles lime in ſeveral reſpects, yet its combinations differ from thoſe of the latter, both in weight, and ſo many other reſpects, as evidently ſhew that there is no reaſon to conſider them as one and the ſame ſubſtance. It is combinable with acids.

Ponderous earth ſuppoſed to be metallic.

From ſeveral properties in which ponderous earth has been obſerved to reſemble metallic ſubſtances, it has been ſuſpected to be of that claſs: but this ſuſpicion has not yet been verified by experiment.

Magneſia.

Moſt of the native ſpecimens of magneſian earth are remarkable for a certain ſoapy or greaſy feel. Of theſe the moſt common are, ſteatites, of a greeniſh colour, and ſoft enough to be ſcraped with the nail; ſoap rock; lapis ollaris, or Spaniſh chalk, of a yellow or whitiſh colour, but rarely black, rather harder than ſteatites, and ſo eaſily wrought and turned, that pots are made of it. Aſbeſtos, amianthus, and the Venetian and Muſcovy talc, are included in this genus.

Epſom ſalt.

The combination of vitriolic acid and magneſia is very ſoluble in water, in which it remarkably differs from the combinations of the ſame acid with the calcareous or ponderous earths. This compound is known by the name of Epſom ſalt, and is found in ſome waters; but is moſt frequently obtained, for commercial purpoſes, from ſea water, after the common ſalt has been extracted by evaporation. If mild volatile alkali be added to a ſolution of Epſom ſalt, the alkali unites with the acid, and part of the earth falls to the bottom, combined with fixed air, which, when well waſhed, is mild magneſia.

Mild magneſia.

Pure magneſia.

Mild magneſia is a light impalpable powder, of a white colour; and forms a paſte with water, which has not much coheſion. Heat drives off its fixed air, and renders it ſomewhat harſher to the feel; but not cauſtic, nor ſoluble in water, like lime. Its taſte is very ſlight in either ſtate. The ſtrongeſt heat does not affect it, if pure. Acids diſſolve it, but alkalis ſcarcely affect it in the dry way.

Union of earths by fuſion.

As the various compounds of bodies uſually poſſeſs properties very different from thoſe of their principles, it is accordingly found that the earths, though infuſible alone, are not ſo when mixed together. The calcareous earth is found to be the ſolvent of other earths, for they are all rendered fuſible by a proper proportion of it. And theſe compounds of two earths will diſſolve ſtill more. So that though one hundred parts of lime will diſſolve very little ſiliceous earth; yet a compoſition of one hundred of lime with fifty of magneſia, will diſſolve one hundred of ſiliceous earth; and this laſt compound will take up more magneſia than the mere calcareous earth could have done. Any three of the earths, in equal parts, will vitrify into a perfect glaſs, provided calcareous earth be one among them.

Suppoſed reduction of the earths.

It has lately been aſſerted, upon good authority, that the argillaceous, calcareous, ponderous, and magneſian earths were reduced to the metallic ſtate by ſtrongly heating them with charcoal*. But however it may be probable from analogy that ſuch reductions may be within the limits of poſſibility, it is at preſent generally underſtood that the metallic matter obtained in theſe experiments conſiſted of iron afforded by the crucibles made uſe of.

The new earths.

We ſhall frequently have occaſion to treat of the five ancient earths, as their various combinations preſent themſelves to our notice: but the three lately diſcovered earthy ſubſtances not having been ſubjected to experiments, except in the laboratories of the diſcoverers, will not again come under diſcuſſion in the preſent work. On this account therefore it will be proper to ſpeak rather more fully reſpecting them than the preceding, and likewiſe to enter more minutely into the deſcription of proceſſes than we might otherwiſe do in this early part of our work.

Characters of adamantine ſpar;

A ſtone has been within a few years brought from the Eaſt, which has received the name of Adamantine Spar. Two varieties are known †. The firſt

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* Journal de Phyſ. 1790.

† Extracts from the Memoir of M. Klaproth. Annales de Chimie, i. 183.

comes

—from China.

comes from China; it is cryſtallized in ſix-ſided priſms, without pyramids, varying in their length from half an inch to one inch, and in breadth near one inch; its colour is grey, of different ſhades. Whole pieces are opake, but thinner fragments are tranſparent: its texture is ſparry, and it breaks with a poliſh. The ſparry texture produces a ſlight ſtriated appearance on its ſurface: its hardneſs is ſo great, that it not only cuts glaſs like a diamond, but it marks rock cryſtal, and other hard ſtones: its ſpecific gravity is 3.710, and in ſome ſpecimens as high as 4.180. Small grains of magnetic calx of iron are ſometimes diſſeminated through this ſtone.

—from Bombay.

The ſecond variety is whiter, more decidedly ſpathoſe in its texture, and the grains of calx of iron are ſmaller, and merely adhere to its ſurface. It is called corundum at Bombay*. At Madras it is known by the name of grinding ſpar.

Analyſis of adamantine ſpar.

M. Klaproth attempted the analyſis of this ſtone by keeping it in fuſion with fifteen times its weight of cauſtic mineral alkali in a ſilver crucible for five hours; then adding boiling water, filtering and ſaturating the alkali with an acid, which conſequently threw down that portion of earth which had combined with the alkali. The undecompoſed part was repeatedly digeſted with concentrated boiling acids. The ſtone was not completely decompoſed till after twelve repetitions of this proceſs; and it was found to conſiſt of two parts clay, and one of an earth not ſoluble by fuſion in alkalis, nor acted upon by acids. It differs

Peculiar earth.

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* Various ſpecimens have been found in France. See De Morveau in the Annales de Chimie, i. 185.

therefore from ſiliceous earth, as well as from the four other ſoluble earths.

Characters of the jargon of Ceylon.

The ſame chemiſt examined the jargon of Ceylon by proceſſes nearly ſimilar*. The colour of this ſtone is pale, of a yellowiſh green, inclining to red; forming upon the whole a kind of ſmoky grey tinge. Its regular figure is that of a four-ſided priſm, terminated by two obtuſe pyramids, compoſed each of four iſoſceles triangles. Its ſpecific gravity exceeds that of any other ſtone, being 4.615.

Pieces of this ſtone being ignited, thrown into water to render it leſs coherent, and then levigated upon porphyry, were fuſed in the ſilver crucible, with a large proportion of cauſtic fixed alkali. The ſolution was treated with water and with marine acid, which took up a ſmall part, and left a reſidue, which was again fuſed with alkali, and treated as before. After ſeveral repetitions of this proceſs, the whole was diſſolved. By ſaturating the acid with mild vegetable alkali, the earthy matter was thrown down. Digeſtion of part of this precipitate with marine, and part with vitriolic acids, indicated, after a due application of chemical methods, a conſiderable portion of ſiliceous earth, with a minute quantity of iron and nickel, and a much larger proportion of an earth which remained ſuſpended on account of its ſolubility in acids. This earth was found to differ in its properties from every other yet known: its ſolubility ſufficiently diſtinguiſhes it from ſilex. When precipitated by mild alkali, it did not become effervescent, like lime or magneſia;

Peculiar earth.

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* See the Memoir at length in the Journal de Phyſique for March 1790.

neither did it, like them, form ſelenite or Epſom ſalt with vitriolic acid. It did not form alum with the vitriolic acid, as clay does. It differed eſſentially from ponderous earth, in its not being precipitable by the Pruſſian alkali; and in forming a ſalt with vitriolic acid, which was exceedingly different from ponderous ſpar. This earth was not ſoluble either in microcoſmic ſalt, or in mineral alkali, when treated by the blow-pipe; but borax diſſolved it. The jargon was found to contain in the hundred parts 31$\frac{1}{2}$ ſilex, $\frac{1}{2}$ calx of iron containing nickel, and 68 of this peculiar earth.

Mineral from New South Wales:

A mineral from New South Wales was put into the hands of Mr. Wedgwood by Sir J. Banks [*]. It conſiſted of a mixture of fine white ſand, a ſoft white earth, ſome colourleſs micaceous particles, and a few black ones, reſembling black mica or black lead. Mr. Wedgwood made ſome experiments upon it, but does not appear to have completely analyſed the maſs, moſt probably on account of its ſmall quantity.

—ſubjected to experiments.

Neither the nitrous nor vitriolic acids, concentrated or diluted, hot or cold, were found to take up any thing from this mineral which could be precipitated by alkalis; excepting that the ſtrong vitriolic acid, by due management, indicated a minute portion of clay. But the marine acid, by digeſtion near its boiling heat, acted on it with frequent exploſive burſts, and took up about one fifth of the whole. The crude mineral, pulverized and calcined, loſt its blackneſs, and one-fourth of its weight, but was found to be as difficult of ſolution as before. Water added to the marine

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[*] Wedgwood in the Philoſ. Tranſ. for 1790, page 306.

ſolution,

EARTHS.

White earthy matter.

ſolution, threw down a white precipitate; and the ſeparation was ſo complete, that, after an addition of eight or nine times the whole bulk of water, there remained nothing in ſolution that alkali could precipitate. This white matter was inſoluble in water, and alſo in the nitrous or vitriolic acids, and in alkaline ſolutions. Strong marine acid took it up as before, by the aſſiſtance of the ſame degree of heat. A certain preciſe quantity of nitrous acid added to the marine ſolution, kept the white matter ſuſpended, even when diluted with water. Strong vitriolic acid did not throw down the white matter from the marine ſolution; but when the quantity added was nearly equal to that of the ſolution, part of the marine acid was extricated in white fumes, with effervefcence. The mixture, heated nearly to boiling, becomes tranſparent, and continues ſo in the cold. This ſolution is alſo precipitable by water, and the precipitate is ſoluble in marine acid.

Marine ſolution of the white matter:

The ſaturated marine ſolution does not cryſtallize by evaporation, but affords a deliqueſcent maſs, which is not corroſive, and parts with its acid in an heat near ignition. Pruſſian alkali does not precipitate the marine ſolution; but all the alkalis, whether mild or cauſtic, occaſioned copious precipitations, which were ſoluble in marine acid, and thence precipitable by water in the original ſtate.

—fuſibility.

This white precipitate is much more fuſible than any of the other ſimple earths. In a heat between 142 and 156 degrees of Wedgwood's thermometer, which is nearly as high as is produced in a ſmall air furnace, it melted in contact with clay, with flint, with chalk, with lime, with magneſia, with pure ponderous earth, and with ponderous ſpar, in ſeveral different experiments. In a hole ſcooped in chalk it run into a ſmooth whitiſh opake bead, not at all adherent to the chalk itſelf; and in a cavity in charcoal it likewiſe fuſed, but did not ſeem to undergo any revivification. Part of this was ſoluble in boiling marine acid, and precipitable by water, as at firſt; but an accident prevented the determination whether the whole was ſoluble.

Peculiar earth.

It appears proper therefore to conſider the white matter as a new earth; directly ſoluble in no menſtruum but marine acid, or perhaps its compounds; not cryſtallizable in this combination; precipitable by water, and not by the Pruſſian alkali; parting with its acid in a heat below ignition; and fuſible in a degree of heat not very much exceeding that required to melt caſt iron.

Other parts of the mineral.

The black ſubſtance which ſeems to have compoſed about one-fifth part of the crude mineral, was found to reſemble plumbago in its leading properties, but its reſidue did not appear to be iron. The remaining three fifths of the mineral which reſiſted the humid attacks in Mr. Wedgwood's experiments, was probably ſilex; but he does not ſpeak of any direct examination of its properties by fuſion with alkalis, the ſparry acid, or otherwiſe.

CHAP. V.

OF THE SIMPLER SALTS; NAMELY, ALKALIS AND ACIDS.

ALKALIS.

THE alkalis are three in number; the vegetable, the mineral, and the volatile alkali. Of theſe the two former are diſtinguiſhed by the general appellation of fixed alkalis. The general properties of fixed alkalis are—1. They change the blue ſyrup of violets to a green. 2. Their taſte is peculiar, and diſagreeably cauſtic, even when diluted with water. 3. They have a ſtrong attraction for water, with which they unite in all proportions, and even attract it in ſufficient quantities from the atmoſphere to become fluid. 4. They combine with acids by a ſtronger affinity than is poſſeſſed by moſt other ſubſtances, at a moderate temperature. 5. Moſt inflammable ſubſtances are acted upon by them. 6. They melt in a moderate heat, and in a ſtronger heat they are volatilized. 7. In the dry way they diſſolve earths, and the calces of metals.

Characters.

Vegetable fixed alkali.

The vegetable fixed alkali is found in ſome ſalts which may be ſaid to be of the mineral kingdom; but it is obtained for all the purpoſes of trade and ſcienc from vegetable matters. Of this there are ſeveral kinds, which differ only in the reſpective quantitie and nature of the impurities they contain. The cendres gravelées is a ſtrong alkali, made by burning the huſks of grapes and wine-lees. Potaſh is procured from

Methods of procuring the vegetable alkali.

from wood-aſhes, and is very far from being pure. Moſt vegetables afford this alkali by burning them, and mixing their aſhes with pure water; which, after decantation or filtering, may be evaporated, and will leave the ſalt behind. The pureſt is obtained by wrapping tartar in wetted brown paper, and placing the parcels in beds or ſtrata alternately with charcoal in a furnace. The whole is then to be ſet on fire, and the fire continued till the blackening ſmoke ceaſes to riſe. If the heat be too intenſe, the alkali will melt, and mix with the impurities of the coal; but when the proceſs is well conducted, the parcels may be taken out entire. By lixiviation or ſolution in pure water, with ſubſequent filtration, evaporation, drying, and calcining in a low heat, the alkali is obtained very white, and contains a conſiderable portion of fixed air. This might be driven off by heat; but it is not neceſſary to be done in that way, as it would be attended with ſome danger of the ſalt corroding the veſſel, and becoming leſs pure. The vegetable alkali is known in the ſhops by the name of ſalt of tartar; but moſt chemiſts in London ſell the impure alkali of potaſh by this name.

Purifying of alkalis.

It is not eaſy to purify the common vegetable alkalis met with in trade, and it is ſeldom attempted. The chemiſt is not under any neceſſity to employ his time in procuring the alkalis abſolutely diſengaged from all other matter, as they will be equally uſeful if kept in combination either with fixed air or with water; in which ſtates the quantities may be more accurately aſcertained by weight when uſed, than if pure; becauſe their rapid attraction for water, in the latter caſe, renders the weighing almoſt impracticable.

Alkalis which contain fixed air, are called mild alkalis.

Alkali of nitre, called fixed nitre.

For very nice purpoſes this alkali may be had from common nitre by deflagration. Nitre conſiſts of the alkali united with an acid. If the fineſt priſmatic nitre be fuſed, and made red-hot in a crucible, and charcoal be then added by degrees, a moſt intenſe combuſtion takes place, during which the acid principle of the ſalt is diſſipated, and the alkali is left in combination only with fixed air. More charcoal muſt be added, as long as it continues to produce the vivid flame; and the heat muſt be raiſed towards the end, in order that the decompoſition of the laſt portions of the nitre may be more completely effected. This ſalt has been improperly called fixed nitre; but there is no difference between the pure ſpecimens of this alkali, whatever ſubject it may have been originally obtained from.

Purification of fixed alkali.

Fixed alkalis may be had in a ſtate of great purity by treatment with ardent ſpirit*. The alkali is firſt to be deprived of moſt of its fixed air by boiling, with about its own weight of quicklime, in twelve parts of water; and the clear ſolution muſt then be evaporated, till it begins to be ſlightly conſiſtent. It muſt then be mixed with the ſtrongeſt ardent ſpirit; and part of the ſpirit may be drawn off by diſtillation. As ſoon as the retort has become cold, it is found to contain a ſolution of pure alkali in ardent ſpirit, which floats

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* Berthollet, in the Journal de Phyſique for 1786.

ALKALIS.

above another aqueous fluid, containing that part of the alkali in cryſtals which ſtill retains its fixed air, and alſo the earthy or metallic impurities of the alkali. The ſpirituous ſolution being decanted off, and evaporated on a ſand bath, affords cryſtals of pure alkali in groups of quadrangular pyramids, which are very deliqueſcent, and ſoluble both in water and ardent ſpirit, with the production of cold.

Oil of tartar.

The vegetable alkali, in its uſual ſtate, deliqueſces in the air, and conſequently unites with water in all proportions. The ſtrong ſolution of this alkali is uſually called oil of tartar per deliquium. Its action on the ſkin produces a ſenſation or feel of greaſineſs, which has given occaſion to this appellation. But it may be had in permanent cryſtals, if enough of fixed air be added to its ſolution.

Mineral alkali.

The mineral alkali in its obvious properties differs but little from the vegetable. Its attractions in general are leſs ſtrong, and the compounds it forms with other bodies are very different from thoſe produced with the vegetable alkali. It uſually contains enough of fixed air to render it much leſs attractive of water than ſalt of tartar. If the quantity of water containing ſalt of ſoda be diminiſhed to about two and a half times the weight of the ſalt; this laſt begins to ſeparate in cryſtals, which do not deliqueſce in the air, but become dry, and fall to powder, by the loſs of that portion of water which entered into the formation of the cryſtals.

Water of cryſtallization.

Efflorescence.

The water which enters into the formation of the cryſtals of any ſalt, is called the water of cryſtallization; and ſuch ſalts as fall to powder by expoſure to the air, are ſaid to effloreſce; the pulverulent ſubſtance thus obtained is ſometimes called an effloreſcence.

Abundance of mineral alkali; in ſea ſalt.

Mineral alkali abounds in vaſt quantities in the waters of the ſea, where it forms half the weight of the common ſalt; and it is ſometimes found in other natural combinations. The effloreſcence, or ſaline matter, which hangs upon old damp walls, conſiſts of this ſalt united to fixed air and water; and in many places in Aſia and Africa it is collected at the ſurface of the earth.

—obtained by incineration.

The mineral alkali in trade is obtained by burning certain plants which grow on the ſea ſhore. It contains ſeveral neutral ſalts in ſmall proportions, which may be ſeparated by cryſtallization; as the alkali, being the moſt ſoluble, remains ſuſpended in water longer than the reſt. Sea ſalt may be decompoſed, and its alkali obtained alone, but not ſufficiently cheap for common uſes. Mr. Turner's proceſs is ſaid * to conſiſt in mixing a quantity of litharge (or calcined lead) with half its weight of common ſalt; which, after trituration with water till it aſſumes a white colour, is left to ſtand ſome hours: after which a decompoſition enſues, the alkali becoming diſengaged with water, while the acid unites with the metallic calx. This laſt, by a proper degree of heat, produces a fine greeniſh yellow pigment, the ſale of which is the chief object of the manufacturer.

Turner's proceſs with common ſalt.

The fixed alkalis are ſtill conſidered as ſimple ſubſtances with regard to the preſent ſtate of our knowledge. It is ſuſpected however that the fixed vegeta-

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* Cronſtedt's Mineralogy, by Magellan, Vol. I. p. 336.

ble alkali may conſiſt of lime in combination with the ſubſtance called phlogiſticated air; and that the mineral alkali is compoſed of magneſia, united to the ſame ſubſtance. The reaſons for theſe ſuppoſitions are:—
*A ſmall quantity of common nitre is produced by expoſing waſhed chalk for ſome months to the exhalations of putrid animal ſubſtances. The repeated diſtillation of ſoap affords volatile alkali, and this contains phlogiſticated air. And a portion of magneſia has been obtained by repeated ſolutions and calcinations of mineral alkali.

Cauſtic ſolution of alkali:

Fixed alkalis, deprived of the fixed air they may contain, by boiling them for a ſhort time with quicklime, which has a ſtronger attraction to the air, and becomes converted into chalk by the proceſs, are then ſaid to be cauſtic, becauſe they act with ſuch energy as to corrode and deſtroy animal ſubſtances. Soap lees is a ſolution of this kind; and the combination of a cauſtic alkali with fat, or oil, is well known by the name of ſoap. If one part of lime, and two of ſalt of ſoda, be boiled in twelve parts of water for a ſhort time, and the filtered lixivium be evaporated till its ſpecific gravity be about 1.375, or, which is the ſame thing, till a phial which would contain an ounce of water would contain an ounce and three eighths of the ſolution; the ſoap may be made by mere mixture of this lye with olive oil, in the proportion of one part of the former with two of the latter, in a glaſs or ſtone ware veſſel. This mixture, being beat up from time to time with a wooden ſpatula, ſoon becomes conſiſtent;

—or ſoap lees.

Soap.

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[*] Thouvenel on Nitre. Chaptal's Elements of Chemiſtry, I. 181. Eng. tranſl. and the authors by him cited.

and in ſeven or eight days it forms a very white and hard ſoap.

Manufacture of ſoap in the large way.

In large manufactories the lye is made no ſtronger than to float an egg, when the workmen begin to form the mixture. To a part of the lye diluted they add an equal quantity of oil, which is ſet on a gentle fire, and agitated. When the combination begins to take place, the reſt of the lye is added, and the whole digeſted by a gentle heat till the ſoap is formed. If well made, it is firm and white, and completely mixes with water, without exhibiting any greaſe on the ſurface. Trials are made of it during the boiling; and the requiſite additions, either of oil or alkali, are made as circumſtances require.

Manufacture of glaſs.

That beautiful product of human induſtry, glaſs, conſiſts of ſiliceous earth diſſolved in an alkali. For this purpoſe, nothing more is neceſſary than to expoſe a proper mixture of ſand, flint, or cryſtal, and fixed alkali, to heat in a furnace till they are incorporated together by fuſion. Simple however as this proceſs may appear, it is by no means an eaſy operation to make a perfect glaſs. If the materials be impure, and contain either metallic particles, or ſuch as cannot be vitrified, the glaſs will be coloured, or defaced with opake ſpecks. If the proportion of alkali exceed two parts to one of earth, the glaſs will be liable to alteration by the action of the air or ſaline ſubſtances, eſpecially acids. If the fuſion be not continued a ſufficient time, the glaſs will be imperfect for want of a ſufficient combination of the materials: and no means have yet been found to prevent the lower part of the pots of glaſs from containing a denſer glaſs than the upper,

Difficulties.

pper, by the ſubſidence of the heavier materials; circumſtance which produces the appearance of hreads or veins in the work, on account of the dif- erent action of the ſeveral parts of the ſame glaſs on ie rays of light. The management of the heat is lſo a material point; for every increaſe of heat extri- ates bubbles of ſome elaſtic ſubſtance; and if the glaſs e uſed during this effervefcence, it will abound with ttle cavities which injure its tranſparency. The im- erfections of glaſs are moſt ſenſibly felt in the con- ruction of optical inſtruments, eſpecially thoſe which e called achromatic.

Frit.

To prevent the ſwelling, at the firſt combination of ie materials, they are previouſly mixed, and expoſed r a conſiderable time in a lower heat than is ſuffi- ent to convert them into glaſs; by which manage- ent great part of the more volatile matters are diſſi- ated. This imperfect combination is called frit, and afterwards fuſed by a ſtronger heat. Glaſs utenſils, nleſs very ſmall, require to be gradually cooled in an en. This operation is called annealing; and is ne- eſſary to prevent their cracking by change of tem- erature, wiping, or ſlight accidental ſcratches.

Manufacture of ſal ammoniac.

The volatile alkali is moſt commonly obtained om ſal ammoniac. This ſalt was formerly imported om Egypt, where it is procured by ſublimation from ot produced by burning the dung of camels. It is ow made in great plenty for the purpoſes of trade Great-Britain. The component parts are volatile kali, and the ſame acid as enters into the compoſi- n of ſea ſalt, and is called the marine acid. The olatile alkali is obtained in an impure liquid ſtate by the manufacturers, who diſtil it from bones, or ſoot, or any other ſubſtance that affords it. To this they add the vitriolic acid, and alſo common ſalt, in due quantities. The vitriolic acid firſt combines with the volatile alkali; but when the common ſalt, which conſiſts of fixed mineral alkali and marine acid, is added, a change of the principles takes place by double elective attraction. The vitriolic acid ſeizes the mineral alkali, and forms the new compound known by the name of Glauber's ſalt; while the marine acid unites with the volatile alkali, and forms ſal ammoniac. By evaporation of the water, theſe ſalts are ſeparated by cryſtallization, and the ſal ammoniac is ſublimed into cakes for ſale.

Volatile alkali:

In order to diſengage the volatile alkali from ſal ammoniac by diſtillation, it is neceſſary to add ſome fixed ſubſtance which ſhall combine with and prevent the marine acid from riſing. Chalk and ſlaked lime are the bodies commonly uſed. If a mixture of two parts of chalk, and one of ſal ammoniac in powder, be expoſed to a ſand heat in a retort, with a receiver adapted, a change of principles by double affinity takes place. The chalk, which conſiſts of lime and fixed air, is decompoſed, and alſo the ſal ammoniac. The lime unites with the marine acid, and forms a fixed earthy ſalt, which remains in the retort; and the fixed air unites with the volatile alkali, and paſſes into the receiver, where it appears in the form of a white hard ſalt of a pungent ſmell. This is the mild volatile alkali, or ſal volatile of the apothecaries and perfumers. It is well known as a ſtimulant uſually put into ſmelling bottles.

—obtained by the medium of chalk:

When

ALKALIS.

—obtained by the medium of lime.

When lime, or calcareous earth deprived of fixed ir, is made uſe of, the decompoſition takes place as efore; but the volatile product has a very different ppearance. It conſiſts, for the moſt part, of a permaently elaſtic or aërial fluid, which very readily comines with water, but may be confined in its elaſtic tate in veſſels over mercury. Moſt of this product vas formerly loſt, becauſe no more of it was detained n the veſſels than had combined with the water which vas driven over by heat from the materials in the reort. But by the uſe of an apparatus upon the priniple of fig. 21, the air may be received and abſorbed y water, without that great loſs which muſt have riſen from the aërial fluid riſing long before the waer, and the quantity of this laſt being inſufficient to etain it.

Alkaline air.

This permanently elaſtic fluid is called alkaline air, nd conſiſts of the pure volatile alkali itſelf. If fixed ir be added to it, a white cloud is formed, conſiſting f mild volatile alkali, which precipitates; and the irs are either diminiſhed or diſappear, according to heir relative proportions to ſaturate each other, or heir reſpective degrees of purity. With the marine cid air, hereafter to be treated of, which is the pure narine acid, it forms ſal ammoniac in the ſame nanner. It unites with equal readineſs with the other cid airs. With water it forms the fluid volatile lkali commonly called ſpirit of ſal ammoniac with ime.

Decompoſition and formation of volatile alkali.

The volatile alkali is decompoſed and formed again n many chemical proceſſes. Theſe, generally ſpeakng, require a more intimate knowledge of chemical

facts

ALKALIS.

facts than the reader can yet be ſuppoſed to poſſeſs, for them to be ſpoken of at length in this place. It will therefore be ſufficient to obſerve, that the dimenſions of alkaline air are greatly enlarged by repeatedly paſſing the electric ſpark or exploſion * through it, or by igniting a piece of earthen-ware in it; and it is by this means rendered incapable of being abſorbed by water, and becomes inflammable. By the admiſſion of vital air, and detonation, the inflammable part is condenſed, and the remainder is found to be phlogiſticated air †. Hence, as well as from other experiments, it is concluded that alkaline air conſiſts of four parts by weight of phlogiſticated, and one of inflammable air.

Characters of acids.

Acids are a genus of ſalts, which may be conſidered as leſs ſimple than the fixed alkalis; becauſe there are experiments which clearly ſhew that they may be decompoſed into principles ſtill ſimpler. Their properties are—1. They change the blue vegetable colours of ſyrup of violets, or tincture of litmus, to a red. 2. Their taſte is ſour, and in general corroſive, unleſs diluted. 3. Moſt of them unite with water in all proportions; and many have ſo ſtrong an attraction for it, that they cannot be exhibited in the ſolid ſtate. 4. They combine with alkalis by a ſtronger affinity than is poſſeſſed by moſt other ſubſtances to thoſe ſalts at a moderate temperature. 6. They act upon earths, and upon moſt inflammable ſubſtances and metals.

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* Prieſtley, II. 239. V. 218. VI. 189.

† Berthollet in Mem. Acad. Par. for 1785, page 324. Alſo Auſtin in Phil. Tranſ. Vol. LXXVIII. p. 387.

Enumeration.

Mineral acids.

The acids found in the mineral kingdom are—the vitriolic acid, known in commerce by the name of oil of vitriol; the nitrous acid, called ſpirit of nitre; the marine acid, called ſpirit of ſalt; the aërial acid, or fixed air; the acid of borax, called ſedative ſalt; the acid of ſpar, or ſparry acid; ſuccinous acid, or acid of amber; the acid of phoſphorus, or phoſphoric acid; the acid of tin; the acid of arſenic; the acid of molybdena; the acid of tungſten, or of wolfram.

Vegetable acids.

The vegetable kingdom affords the acids of lemons; of apples, or unripe fruits; of galls; of benzoin; of tartar; of ſugar, or ſorrel; the empyreumatic acid of tartar; the empyreumatic acid of ſugar, or mucilage; the empyreumatic acid of wood; the acid of camphor; the acid of cork; and the acetous acid, or vinegar.

Animal acids.

The animal kingdom affords the acid of milk; the acid of ſugar of milk; the acid of ants; the acid of Pruſſian blue; the acid of fat; the acid of the ſtone of the bladder; and the acid of ſilkworms.

Inflammable additions to acids.

When an inflammable ſubſtance is added to a ſtrong acid, the effects in general are, that the acid is rendered more volatile, and part flies off in an elaſtic orm, which has various properties, according to the nature and properties of the acid, as will be hereafter hewn.

Theory.

In the theory of phlogiſton, acids are ſuppoſed to ontain that principle, and to be capable of uniting with it in various proportions. When they have received a larger proportion, they are rendered more volatile, and fly off in the elaſtic form; and when they

Theory.

they have a leſs than the uſual proportion of it, they are ſaid to be dephlogiſticated, and act more ſtrongly on phlogiſtic bodies. In the new theory, acids are ſuppoſed to conſiſt each of a peculiar baſe united to vital air in a fixed ſtate. If they act on a combuſtible body, and become deprived of part of their vital air by its action, their conſtitution is changed, and their baſe is more diſpoſed to fly off; but if by any means they obtain an over-proportion of vital air, their action on combuſtible bodies is more efficacious.

Vital air a component part of acids.

Moſt of the phlogiſtian chemiſts admit of the exiſtence of vital air, as a component part of acids; a poſition which ſeems indeed to be as well eſtabliſhed upon facts as any part of the ſcience of chemiſtry.

Neutral ſalts.

Combinations of alkalis with acids are called neutral ſalts.

C H A P.

C H A P. IX.

OF METALLIC BODIES IN GENERAL.

CHARACTERS OF METALS.

METALLIC ſubſtances are very eaſily diſtinguiſhable from all other bodies in nature, by heir very great weight, and that opake ſhining ap- earance which is called the metallic ſplendour or rilliancy. Very few ſubſtances have half the ſpecific ravity of the lighteſt among the metals. They are ll fuſible, though at very different temperatures; and the fuſion be made in cloſe veſſels, they fix again by old, without having ſuffered any change but that of xternal figure, which muſt be produced in all bodies hich have been either liquefied or volatilized; namely, ey aſſume the form of the veſſel which contains them. ome of them may be extended conſiderably by the ammer, without breaking them. This property is alled malleability; and the metallic bodies which poſſeſs are called entire metals, or metals, in contradiſtinction ſuch as are more brittle, and are called ſemi-metals. etallic ſubſtances are alſo called perfect and imper- ct. The perfect are ſuch as undergo no laſting change f their properties by any heat we can apply to them, leaſt in common furnaces. The imperfect metals, hen expoſed to a ſtrong heat, with acceſs of vital r, are changed, by a proceſs ſimilar to burning, and in me of them with an actual flame, into a brittle dull bſtance called a calx, which is heavier than the tal it came from, though its ſpecific gravity is not

Entire metals.

Perfect and imperfect metals.

Calces.

Acids.

ſo great. Some are even converted into acids. If the calx of a metal be expoſed to ſtrong heat in a cloſed veſſel, with ſome inflammable matter, it recovers its metallic ſtate. This is called reduction or reviving of the metal.

Enumeration of metals.

All metals are imperfect except gold, ſilver, and platina. The imperfect metals are, mercury, lead, copper, iron, and tin; and the ſemi-metals are, biſmuth, nickel, arſenic, cobalt, zinc, antimony, mangaueſe, wolfram, molybdena, and uranite. The names arſenic, antimony, mangaueſe, wolfram, and molybdena, being uſed to denote the mineral ſubſtance from which the ſemi-metals are obtained, the ſemi-metals themſelves are diſtinguiſhed by the name of regulus of arſenic, regulus of antimony, and ſo forth; though modern chemiſts often uſe the ſimple term to denote the ſemi-metal itſelf alone.

Regulus.

Freezing point of metals.

Metals, like other fuſible bodies, have each a fixed temperature, or freezing point, at which they become ſolid. They aſſume a cryſtallized figure in cooling, which is different in each, and may be ſeen by fuſing them in melting pots with a hole in the bottom, ſtopped with a ſtopper; for in this caſe, if the ſurface be ſuffered to congeal, and the fluid metal beneath be ſuffered to run out through the hole, the under ſurface of the remaining metal will be curiouſly cryſtallized. The ſpecific gravity of metallic ſubſtances is very conſiderably affected by the gradual or haſty cooling, or tranſition from the fluid to the ſolid ſtate. Hammering renders them harder and more elaſtic; but this effect is deſtroyed by ignition.

Cryſtallization.

Affinities.

The affinities of metals to each other are various.

Some will not unite at all; others mix very readily, and even combine together. On this property is founded the art of ſoldering; which conſiſts in joining two pieces of metal together by heating them, with a thin piece or plate of a more fuſible metal interpoſed between them. Thus tin is a ſolder for lead; braſs, gold, or ſilver, are ſolders for iron, &c.

Solders.

Countries moſt abundant with metals.

Mountainous diſtricts, where the ſurface of the globe has been thrown up or diſturbed, in remote ages, by earthquakes, volcanos, or other great convulſions of nature, are the moſt abundant in metallic bodies. In digging into the bowels of the earth, the various materials are moſtly found diſpoſed in ſtrata or beds, which in plains lie level, but in mountains are inclined; whence it happens that in mountainous countries ſome ſtrata are often expoſed to the day, which would elſe have been too deeply lodged to be come at by human art. It is in the ſtratified mountains that metals are uſually found, moſtly in a ſtate of combination either with ſulphur or arſenic, or in the ſtate of a calx. They are alſo found, though leſs frequently, in the metallic or native ſtate.

Ores. Veins. Mines. Matrix.

The combinations, or earthy bodies, which contain metals in ſufficient quantity to be worth extracting, are called ores. Iron ore ſometimes forms entire mountains; but in general the metallic part of a mountain is very inconſiderable in proportion to the whole. The ores run either parallel to the ſtony ſtrata, though far from having the ſame regularity of thickneſs, or they croſs the ſtrata in all directions. Theſe metallic ſtrata are called veins. The cavity formed by art in the earth, for the extraction of metals or any other mineral bodies, is called a mine. The ſtone wherein a metallic ore is uſually bedded, is called its matrix. Theſe are not peculiarly appropriated to any metal, though ſome ſtones more frequently accompany metals than others.

Operations for extracting metals from ores.

The general operations by which metals are obtained from ores are—1. The minerals are ſelected; and ſuch only are taken as from experience are known, by the external figure or appearance, to contain metal. 2. They are reduced to powder; and the lighter parts waſhed away, by means of water, in a ſhallow trough. 3. The volatile parts are diſſipated by the operation called roaſting. 4. The ores are ſmelted by throwing them into the midſt of the fuel of a furnace, with earthy ſubſtances which are diſpoſed to run into glaſs. In this operation, the glaſſy matter, called ſcoria, in ſome meaſure produces the effect of rendering the lower part of the furnace a cloſed veſſel; and the fuel revives the metal, which in the ore is uſually of the nature of calx. The revived metal being much denſer than the ſcoria, falls to the bottom, and is ſuffered to run out by proper openings. Theſe are the general operations, but they are not all neceſſary in all caſes; and the particular practice with the ſeveral ores of each metal, muſt vary according to the properties of the metal itſelf, and the different ſubſtances it is united with.

Aſſaying, or eſſaying.

The extraction of metals from ores, in the ſmall way, which is neceſſary to be made in order to aſcertain whether the ſpecimens are worth working, is called aſſaying or eſſaying. In theſe ſmall trials the fuſibility of the pounded ore is increaſed by an addition of black flux, which is an impure alkali, formed

by

Humid way.

by mixing two parts of tartar with one of nitre, and ſetting them on fire. Metallic ores may be very accurately aſſayed by ſolution and precipitation in the humid way.

Theory.

The theory of the calcination and reduction of metals, according to the ſyſtem of phlogiſton, is as follows:—Metals, like all other inflammable bodies, contain phlogiſton united to a baſe. While the vital part of the air unites with the baſe, the phlogiſton is diſengaged, and leaves behind it the combination called a calx, which is heavier than the metal, becauſe the air received exceeds the weight of the phlogiſton diſengaged.—In the antiphlogiſtic ſyſtem, metals are conſidered as ſimple ſubſtances, which are converted into calces by their union with vital air, and are revived by heating them with any other matter which is more combuſtible than themſelves; that is to ſay, which has a ſtronger attraction for vital air, at the temperature of reduction. Some of the maintainers of phlogiſton admit that the vital air unites with that principle of inflammability, and compoſes a ſubſtance which combines with the baſe of the metal. Here the fact agrees with the ſtatement of the antiphlogiſtians, but the explanation is leſs ſimple.

Mixture of metals.

Moſt metals will uniformly mix with each other; and the ſpecific gravity of the compound is ſeldom ſuch as would have been deduced from the ſuppoſition of a mere mixture, or ſimple appoſition of parts. Their fuſibility is likewiſe greatly changed by mixture, and according to no certain rule yet diſcovered.

Alloys.

Mixtures of metals are frequently called alloys. But the word alloy, or allay, is moſtly uſed to denote a portion of metal which is added to the precious metals, gold or ſilver.

Solubility of metals in acids.

Metals are moſtly ſoluble in acids, with which they form ſalts. When a metal is added to an acid, the general effect produced is the ſame as would have ariſen from the addition of any other combuſtible ſubſtance to the acid. If an alkali or earth be added to a metallic ſolution, the metal falls to the bottom in the form of a calx. But if a metal which has a ſtronger affinity with the acid than the metal already diſſolved has, be added to ſuch a ſolution, the former metal will fall to the bottom in its metallic ſtate, and the latter will be diſſolved without cauſing any of the eſcape of elaſtic fluid, and other appearances, which would have taken place if it had been applied to the mere acid; notwithſtanding which, the latter metal, if precipitated by an incombuſtible ſubſtance, ſuch as an alkali or earth, will be in the ſtate of a calx.

Precipitation.

Inferences.

It is evident, from theſe facts, that the action of acids upon metals is ſimilar to that of heat with acceſs of vital air; and of courſe may be accounted for, upon both the theories of chemiſtry, in the ſame manner as combuſtion itſelf. According to the original theory, when an acid acts upon a metal, it unites with the baſe of the metal, and expels the phlogiſton; which either riſes alone, in the form of inflammable air; or, combining with the acid itſelf, forms an acid air, or volatile acid. If an alkali be added, the calx falls down, combined with air, which it obtains either from the alkali or the acid; but if a metal be added, the phlogiſton of this laſt, uniting with the calx of the former, revives it, and it falls down in its metallic ſtate. The new theory

Original theory.

New theory.

theory may be applied as follows: When a metal is added to an acid, it attracts vital air either from the acid itſelf or from the water. If the former, the acid itſelf is decompoſed; and its baſe, combined with an under proportion of vital air, ariſes in the form of volatile acid, or acid air. But, if the latter, the water itſelf is decompoſed, its vital air combining with the metal, and its inflammable air flying off: in this caſe, the acid is ſuppoſed to do nothing more than hold the calx in ſolution, and by that means facilitate the action of the water, which would be much leſs effectual if the calx were ſuffered, on account of its inſolubility, to remain upon and defend the ſurface of the metal; which, by reaſon of its inſolubility in mere water, it would not fail to do, if the acid were not preſent.

Precipitation of metals by metals.

Metals are precipitated by each other in the ſame order, or nearly ſo, in all acids. Hence it is inferred, that this effect is produced by the reaction of ſome common principle, either of the metal or of the acids. In the old theory, a metal which has a ſtronger attraction for phlogiſton, will take that principle from another metal which holds it more weakly; and of courſe the latter will cauſe the former to be precipitated in its metallic form. In the new theory, a contrary tranſition of vital air from the acid produces the ſame effect: for if a metal has a ſtronger attraction for vital air than is exerted by another metal already in ſolution, it will deprive this laſt of it, and cauſe it to fall down in the metallic ſtate.

Limit of ſolution in acids.

Acids diſſolve metals only in their calciform ſtate; and there is a certain limit near which the ſolution is

METALLIC SUBSTANCES.

beſt performed. If an acid be of ſuch a nature as to be incapable of calcining a metal, it will not diſſolve it, though the ſame acid would diſſolve the calx if preſented to it; and if the calcination be carried on too far, the calx will likewiſe be inſoluble. To explain this according to the two theories, it may be obſerved, that acids calcine metals by virtue of their attraction for phlogiſton, and ſuſpend the calx by virtue of the ſame power exerted on the remaining portion of phlogiſton, of which they cannot in general diveſt the calx; conſequently, if the calx be diveſted of this portion, it will be inſoluble. Or, in the other theory, the ſimple metal attracts as much vital air from the acid as is ſufficient to convert itſelf into a calx, but not enough to ſaturate it with that principle: it is therefore ſuſpended, in conſequence of its remaining weak attraction for the vital air of the acid. But if the calcination be complete, that is to ſay, if the affinity of the metal for vital air be perfectly ſatisfied, the remaining attraction of the metal for vital air will ceaſe, and it will be inſoluble.

Theory of ſolution.

Action of various ſubſtances on metals.

The direct action of alkaline ſalts upon metals is not conſiderable: ſulphur combines with moſt of them readily in the way of fuſion; and the combination of ſulphur with an alkali, called liver of ſulphur, is a powerful ſolvent of all metals except zinc. Nitre, heated with metals, acts in the ſame manner as it does with other inflammable bodies—it deflagrates, and the metals become calcined. The perfect metals reſiſt the action of nitre.

B O O K II.

PARTICULAR CHEMISTRY.

SECTION II.

CONCERNING THE MINERAL ACIDS, AND OTHER MINERAL BODIES WHICH ARE CONVERTIBLE INTO ACIDS.

CHAP. I.

OF SULPHUR, VITRIOLIC ACID, AND THE COMBINATIONS THEY FORM WITH OTHER BODIES.

SULPHUR.

SULPHUR, or brimſtone, is a well-known hard, brittle, inflammable ſubſtance, of an opake yellow colour. It is found more or leſs pure in the neighbourhood of volcanos, where moſt probably it is always expelled from ſome previous ſtate of combination by the heat of ſubterraneous fires. It is a very common ingredient in a great variety of minerals and ores; but it is extracted for ſale chiefly from a ſtone called pyrites. This ſtone is often of an irregular globular figure; and, when broken, is found to have a radiated texture, the fibres uſually converging towards a centre. Their great weight, and the ſhining golden colour

Pyrites.

SULPHUR. Pyrites.

colour of ſome ſpecimens, often lead the ignorant to ſuppoſe them rich in precious metal. The contents of the pyrites are various; but the kind here ſpoken of contains from one ſixth to one third of its weight of ſulphur, one eighth to five eighths iron in a calcined ſtate, and the reſt clay and ſiliceous earth. They give fire plentifully with the ſteel; whence their name is derived. A moderate heat will expel the ſulphur from pyrites, as it is conſiderably volatile. In the large way, in Germany and Italy, the pyrites are put into earthen cucurbits, diſpoſed in a furnace in ſuch a manner that when the ſulphureous part melts, it runs into veſſels filled with water, and there congeals.

Diſtillation of ſulphur:

—ſublimation.

Sublimation is neceſſary to deprive ſulphur of the accidental impurities it may contain. This may be done in an earthen cucurbit ſet on a ſand bath, with a head properly adapted. The ſulphur riſes by a very gentle heat, little more than is ſufficient to melt it; and the fine ſublimate thus obtained is called flowers of brimſtone.

Action of water upon ſulphur.

Water has no immediate action on ſulphur. It is ſaid, however, to ſoften the outſide by long contact with it; and if ſulphur be heated nearly to ſuch a degree as to ſet it on fire, and then poured into water, it becomes ſoft, and partly tranſparent. In proceſs of time it recovers its original hardneſs and opacity. If ſteam of water be paſſed over ſulphur contained in a heated earthen tube, inflammable air is extricated either from the ſulphur or the water, and comes out at the end of the tube*. The experiment is troubleſome on account of the ſulphur ſubliming.

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* Prieſtley, VI. 150.

SULPHUR.

The combinations of ſulphur with earths or alkalis are called hepars, or livers of ſulphur, from their colour. There is no perceptible action between ſulphur and ſiliceous earth. Argillaceous earth has very little action upon it in the direct way; but lime unites readily with it. If freſh quick-lime and flowers of ſulphur be mixed, and water be added a little at a time, the heat of the lime will be ſufficient to produce the combination. On addition of more water, it becomes reddiſh, and emits a fetid ſmell of rotten eggs, which is common to all the hepars. The more cauſtic the lime, the deeper the colour of the hepar. The pure fixed alkalis decompoſe calcareous hepar, by virtue of their ſtronger affinity to the ſulphur: and any acid whatever decompoſes it, by attracting the lime; the ſulphur at the ſame time falling to the bottom in the form of a ſubtle powder, formerly called magiſtery of ſulphur.

Combination of ſulphur; with lime;

Pure ponderous earth boiled in water with ſulphur, has but little action upon it: but in the dry way, when ponderous ſpar, or the combination of vitriolic acid and ponderous earth, is ſtrongly heated in a crucible with charcoal, a coherent maſs is formed, which is ſoluble in water, with the ſmell and other hepatic characters; and if any acid be added which will form a ſoluble ſalt with the ponderous earth, a precipitate of ſulphur will be obtained.

—with ponderous earth:

If a ſmall quantity of magneſia, and an equal quantity of flowers of ſulphur, be incloſed in a veſſel perfectly filled up with diſtilled water, and well ſtopped, and then expoſed to heat by immerſion in boiling water for ſeveral hours, a combination will take place, and

—with magneſia.

and the water will contain a magneſian liver of ſulphur; from which the earth may be precipitated by the addition of an alkali, which will unite with the ſulphur; or the ſulphur may be precipitated by an acid, which will combine with the earth.

Combination of ſulphur with fixed alkalis.

The fixed alkalis combine very readily with ſulphur, either in the moiſt or dry way, whether they be in a pure or cauſtic ſtate, or combined with fixed air; though more ſtrongly in the former than the latter caſe. If a ſolution of fixed alkali in water be boiled with half its weight of powdered ſulphur, a combination takes place, and liver of ſulphur is formed. Or, if equal parts of dry alkali and powdered ſulphur be melted in a crucible, and poured out on a flat poliſhed ſtone, as ſoon as the fuſion is complete, the combination will be of a liver colour, and is the ſolid hepar. If it be made with a pure or cauſtic alkali, its colour is deeper, and its characteriſtic properties more intenſe, than when a mild alkali is uſed. A ſolution of the ſolid hepar in water forms preciſely the ſame ſubſtance as the preparation made in the moiſt way.

Hepatic air.

The peculiar fetid ſmell of the ſolid hepar when moiſtened, or of its ſolution, is produced by the emiſſion of a permanently elaſtic fluid, called hepatic air. This ſmell, when ſtrong, is inſupportable, and ſuddenly deſtroys animal life. Hepatic air is very ſoluble in water, which it converts into a ſtate perfectly reſembling that of the ſulphureous mineral ſprings. It renders ſyrup of violets green, blackens the calces of lead and biſmuth, and the ſurface of ſilver. Vital air decompoſes it, and cauſes ſulphur to be depoſited. It detonates with vital air when ſet on fire. It is not clearly aſcertained in what manner the ſulphur is ſuſpended in hepatic air. Sulphur, melted by the burning glaſs, in inflammable air over mercury, produces a fluid which has the properties of hepatic air; and *if inflammable air be paſſed through melted ſulphur, it becomes converted into hepatic air. As this air is not obtained from hepar unleſs water be preſent, it has been ſuppoſed to conſiſt of ſulphur volatilized, in combination with inflammable air, extricated by a decompoſition of the water; whoſe other component part, namely, vital air, is ſuppoſed to unite with the ſulphur. It is even aſſerted that the reſidue contains vitriolated tartar.

Hepatic air.

Fluid volatile alkali has very little action on ſulphur; but a volatile hepar may be produced by the union of alkaline air with ſulphur in the vaporous ſtate. If equal parts of quick-lime and ſal ammoniac be mixed together with half a part of ſulphur, and diſtilled with the pneumatic apparatus (fig. 15 and 21), with a ſmall quantity of water in the receiver, a reddiſh yellow hepatic liquor will be obtained, which is the volatile hepar, and was formerly known by the name of the fuming liquor of Boyle; ſo called from its inventor, and from the white fumes it emits in the air.

Volatile liver of ſulphur.

Sulphur combines with moſt metallic bodies in the dry way. Oils likewiſe diſſolve it, and form compounds called balſams.

Balſams.

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* Haſſenfratz in Phil. Tranſ. Vol. LXXVII. p. 306.

When

SULPHUR.

Combuſtion of ſulphur.

When ſulphur is heated in an open veſſel, it melts; and ſoon afterwards emits a blueiſh flame, viſible in the dark; but which, in open day light, has the appearance of a white fume. This flame has a ſuffocating ſmell; and has ſo little heat that it will not ſet fire to flax, and may even be ſuffered to play againſt the palm of the hand without any conſiderable inconvenience. In this way the ſulphur may be entirely conſumed. If the heat be ſtill augmented, the ſulphur boils, and ſuddenly burſts into a much more luminous flame; the ſame ſuffocating vapour ſtill continuing to be emitted.

Volatile vitriolic acid.

The ſuffocating vapour of ſulphur is imbibed by water, with which it forms the fluid called volatile vitriolic acid. If this fluid be expoſed for a time to the air, it loſes the ſulphureous ſmell it had at firſt, and the acid becomes more fixed. It is then the fluid which was formerly called ſpirit of vitriol. Much of the water may be driven off by heat; and the denſe acid which remains is the vitriolic acid, commonly called oil of vitriol: a name which was probably given to it from the little noiſe it makes when poured out; and the unctuous feel it has when rubbed between the fingers, produced by its corroding and deſtroying the ſkin, with which it forms a ſoapy compound.

Oil of vitriol.

Vitriol of iron.

The pyrites before mentioned, which conſiſt, for the moſt part, of ſulphur and iron, are found to be converted into the ſalt called vitriol of iron by expoſure to air and moiſture. In this natural proceſs the pyrites break, and fall in pieces; and if the change take place rapidly, a conſiderable increaſe of temperature follows, which is ſometimes ſufficient to ſet the maſs on fire. By conducting this operation in an accurate way, it is found that vital air is abſorbed. The vitriol is obtained by ſolution in water, and ſubſequent evaporation; by which the cryſtals of the ſalt are ſeparated from the earthy impurities which were not ſuſpended in the water.

Diſtillation of vitriol.

The vitriolic acid was formerly obtained by diſtillation from vitriol of iron. When this ſalt is expoſed to heat, the vitriolic acid comes over, at firſt attended with a large quantity of volatile ſulphureous vapour; and, towards the end, there is a production of pure dephlogiſticated air. The acid which riſes laſt has a concrete cryſtalline form. The acid obtained in this proceſs is black, and requires to be purified by a ſecond diſtillation, or rectification, in which the volatile ſulphureous acid comes over, and leaves the denſe vitriolic acid behind.

Manufacture of vitriolic acid.

Moſt of the vitriolic acid now uſed is produced by he combuſtion of ſulphur. There are three conditions requiſite in this operation. Vital air muſt be reſent, to maintain the combuſtion; the veſſel muſt be loſe, to prevent the eſcape of the volatile matter which iſes; and water muſt be preſent, to imbibe it. For heſe purpoſes, a mixture of eight parts of ſulphur with one of nitre is placed in a proper veſſel, incloſed within chamber of conſiderable ſize, lined on all ſides with lead, and covered at bottom with a ſhallow ſtratum of water. The mixture being ſet on fire, and ſhut up, will burn for a conſiderable time, by virtue of the ſupply of vital air which nitre gives out when heated; nd the water, imbibing the ſulphureous vapours, beomes gradually more and more acid, after repeated combuſtions; and the acid is afterwards concentrated by diſtillation.

Characters of vitriolic acid.

Pure vitriolic acid is colourleſs, and emits no fumes. It ſtrongly attracts water, which it takes from the atmoſphere very rapidly, and in large quantities, if ſuffered to remain in an open veſſel. If it be mixed with water, it produces an inſtantaneous heat, nearly equal to that of ebullition. Its action upon all the earths except the ſiliceous, upon the alkaline ſalts, upon many metals, and almoſt every other combuſtible ſubſtance, is very ſtrong.

Combination of vitriolic acid and clay.

With argillaceous earth it forms alum. This well-known ſalt has a peculiar auſtere or aſtringent taſte; is ſoluble in about fifteen times its weight of water, at the temperature of 60°, and in a much leſs quantity at higher temperatures; from which it may be ſeparated in the form of permanent cryſtals. It fuſes at a moderate heat, and froths up till its water of cryſtallization is evaporated; at which period it has the form of a white friable ſubſtance, called calcined alum, which retains the greateſt part of its acid when not too much heated; and may again be reſtored to its original form by adding the water it had loſt by the heat.

Preparation of alum.

Alum is not made for the purpoſes of commerce by a direct combination of the vitriolic acid and clay, but is extracted from ſubſtances uſually called alum ores, which either are, or probably were originally, compoſed of clay and ſulphur. From ſuch as contain the alum ready formed, as is the caſe with earths of this kind found in the neighbourhood of volcanos, it is extracted by lixiviation in water, and ſubſequent evaporation. But other ſubſtances, ſuch as pyrites and

alum

VITRIOLIC ACID.

alum ſlates, require to be burned or expoſed to the air and moiſture for a time, before any alum can be had from them. Theſe proceſſes convert the ſulphur into vitriolic acid. Alum works have long been eſtabliſhed in Britain, and many other parts of the world.

The acid in alum is not ſaturated. If a ſolution of alum be boiled upon clay, a conſiderable portion of the latter will unite with the ſalt, and form a combination which is much leſs ſoluble than the alum itſelf.

Vitriolic acid with lime, p. 104.

With calcareous earth the vitriolic acid forms gypſum, or plaſter of Paris. This ſaline ſubſtance is plentifully found in nature; and is known by different names, according to its texture and external appearance. The lapis ſpecularis and alabaſter are of this kind. It requires about five hundred times its weight of water to diſſolve it at the temperature of 60°, and has for that reaſon been reckoned an earth. Its chief uſe has been already adverted to.

—with ponderous earth, p. 105:

With ponderous earth the vitriolic acid forms the ponderous ſpar, or marmor metallicum.

—with magneſia, p. 106:

With magneſia it forms Epſom ſalt, which has a bitter taſte. This is ſoluble in its own weight of water, at the temperature of 60°; and by evaporation it is recovered in cryſtals, which are diſpoſed to effloreſce, or become converted into a dry powder by expoſure to air.

—with vegetable alkali.

With the vegetable alkali this acid forms a ſalt commonly called vitriolated tartar, which is ſoluble in about ſixteen times its weight of water, at the temperature of 60°; and from which it may again be recovered by evaporation in the form of permanent cryſtals.

VITRIOLIC ACID.

Vitriolic acid with mineral alkali:

With the mineral or marine alkali, the vitriolic acid forms Glauber's ſalt, which requires only three times its weight of water to diſſolve it at the ſame temperature. It is more ſoluble in hot than cold water; and may therefore be ſeparated from a hot ſaturated ſolution, either by cooling or by evaporation. Its cryſtals are uſually large and well formed; but they loſe their water of cryſtallization, which amounts to near half their weight, by expoſure to the air, and fall into an eflloreſcence, or white powder.

—with volatile alkali:

The combination of the vitriolic acid with volatile alkali, is called vitriolic ammoniac. It is ſoluble in twice its weight of cold or an equal weight of hot water; and affords cryſtals either by cooling or evaporation, which are permanent, or ſlightly diſpoſed to attract moiſture and deliqueſce. Some chemiſts aſſert that it is volatile, and others affirm the contrary. Upon examination, it would probably be found that the acid or alkali, or both, are decompoſed by heat.

— with combuſtible matter.

Aeriform vitriolic acid.

Page 134.

When any combuſtible ſubſtance is added to the concentrated vitriolic acid, the fluid becomes black; and emits white vapours, which are of an exceedingly pungent ſulphureous ſmell; and, if received over mercury, are found to conſiſt of a peculiar aeriform fluid, which is not condenſable into the fluid ſtate except by a very great degree of cold *. It is ſoluble in water, which it converts into volatile vitriolic acid, of exactly the ſame nature as that obtained by the combuſtion of ſulphur. Whence it follows, that the fumes of ſulphur conſiſt of this kind of air, rendered viſible by

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* This was effected by M. Monge. See Fourcroy's Chemiſtry, Vol. I. p. xxxi.

VITRIOLIC ACID.

the moiſture it meets and combines with in the atmoſphere. Boiling vitriolic acid acts upon moſt metals, and affords vitriolic acid air, and with ſome of them ſulphur; but with ſuch metals as it can act upon when conſiderably diluted, it affords inflammable air. When this acid is diſtilled from metals to dryneſs, the latter product is vital air.

Sulphureous acid.

The ſulphureous or volatile vitriolic acid forms ſaline combinations with earths, alkalis, and metals; but its attraction to theſe baſes is much leſs than that of the vitriolic acid. Expoſure to the air for a length of time changes theſe ſalts into common vitriolic ſalts, in the ſame manner, doubtleſs, as it changes the ſulphureous acid into the common vitriolic acid.

Characters of vitriolic acid air.

Vitriolic acid air is heavier than common air; and, like every other permanently elaſtic fluid, except vital air and its compounds, it extinguiſhes combuſtion, and deſtroys animal life. If alkaline air be mixed with it, the airs combine, and form a beautiful white cloud, which becomes condenſed, and is found to be vitriolic ammoniac; at the ſame time that a yellow ſubſtance is ſeparated, which ſeems to be ſulphur. Water impregnated with this air may be frozen without parting with it; and if ſuch impregnated water be expoſed to heat for many days in a glaſs veſſel hermetically ſealed (that is to ſay, cloſed by melting its aperture with a blow-pipe), it depoſits ſulphur *.

Vitriolic acid converted into ſulphur.

The converſion of ſulphur into the vitriolic acid, and, contrary-wiſe, of the acid into ſulphur, being effects of great importance in chemical theory; it became a deſirable object to perform the latter, in order

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* Prieſtley, IV. 124.

to confirm ſuch reaſoning as was adopted reſpecting the former. As it is evident that ſulphur becomes vitriolic acid by combuſtion, it muſt follow by analogy, from what happens in the revival or reduction of burned metals, or metallic calces, that ſulphur might be revived from vitriolic acid, by expoſing it to heat with ſome more combuſtible ſubſtance. A difficulty however preſented itſelf in this attempt, which was, that the vitriolic acid, being rendered volatile by the addition of a combuſtible body, would elude the attempt to expoſe it to a conſiderable heat. This, no doubt, was the circumſtance that directed the attention of the great founder of the theory of phlogiſton (Stahl) to the neutral ſalts; in which the acid is not only highly concentrated, but combined with a more fixed body, namely, the alkali. He fuſed equal parts of fixed alkali and vitriolated tartar in a crucible; to which he added half a part of powdered charcoal. This mixture being well ſtirred together, and heated ſtrongly for a very ſhort ſpace of time, was poured out, all ſparkling, upon a ſmooth ſtone previouſly greaſed. The compound, when cooled, was found to be a true liver of ſulphur; from which, after ſolution in water, and precipitation by adding an acid, the ſulphur was obtained.

Stahl's experiment for obtaining ſulphur from vitriolic acid.

Electricity.

When the electric ſpark paſſes between two ſurfaces of vitriolic acid confined in a bended glaſs tube, there is a production of vital air.

Recapitulation and theory.

Such are the principal facts relating to ſulphur and the vitriolic acid; which, when conſidered with a view to theoretical arrangement, are found to be more immediately connected than at firſt view they may ſeem

to

Theory.

to be. The combuſtion of ſulphur is of the ſame nature as every other combuſtion. Vital air is abſorbed, and the inflammable principle is ſuppoſed to be extricated. The ſulphur, thus deprived of its phlogiſton, and united to vital air, becomes an acid; which is not completely changed until, by ſubſequent expoſure to the common air, it has imbibed ſtill more of the vital part, and the remaining phlogiſton has been diſſipated. The decompoſition of pyrites is a phenomenon of the ſame kind, but is performed more gradually, and of courſe with the accumulation of leſs heat. The ſulphur of theſe combinations attracts the vital part of the air by an action which is ſuppoſed to be increaſed by the ſtrong tendency of the iron to combine with the acid that reſults from the union; the phlogiſton being diſſipated for the ſame reaſon. Inſtead, therefore, of a combination of iron and ſulphur, they become converted into vitriol, in which an acid is found: and as this proceſs conſiſts of the abſorption of vital air, and diſengagement of phlogiſton, it is a true combuſtion; with this only modification, that the heat is ſeldom extricated ſo rapidly as to produce the appearances of ignition and flame, but is conducted off by the ſurrounding bodies nearly as faſt as it is generated.

Decompoſition of pyrites.

Black vitriolic acid.

In the diſtillation of vitriolic acid from vitriol of iron, the acid is rendered black and ſulphureous from the iron, which was not completely dephlogiſticated or calcined during its original combination with the acid: for the phlogiſton of the iron is ſuppoſed, in this diſtillation, to unite with the acid, and form ſulphur; while the portion of the vital air which con-

VITRIOLIC ACID.
Theory.

tributed to convert that ſulphur into acid, unites with the calx, and is afterwards driven off towards the end of the proceſs. A cryſtalline or concrete form of the acid is ſometimes produced by its holding the vitriolic acid air in ſolution. If this be driven off by heat, the acid will be pure. Hence it is clear that the volatile vitriolic acid differs in fact from the pure vitriolic acid, in the circumſtance that it holds ſulphur in ſolution. And the vitriolic acid air is the ſame acid with ſulphur, but with much leſs water, if any.

Mutual action of vitriolic acid and combuſtible bodies.

The change in the vitriolic acid produced by the addition of a combuſtible ſubſtance, is explained with equal facility; for it is the reverſe of the inflammation of ſulphur. The pure air of the acid is abſorbed by the combuſtible body; while the phlogiſton of this laſt unites with the baſe of the ſulphur, and forms ſulphur. This ſulphur renders the acid volatile; and it comes over in the aerial form, together with water. If the combuſtible body be of ſuch a nature as to leave a fixed reſidue, to which the laſt portions of acid may unite after all the water is diſſipated, ſulphur wil come over alone. Or if all the ſulphur be driven o either with the water or after it, the laſt product wil conſiſt of the vital air which adhered to the reſidue or fixed calx of the combuſtible body. When the diluted vitriolic acid acts upon a metal, and diſengage inflammable air, the acid unites entirely, and withou decompoſition, to the calx, and the phlogiſton flies o in the aerial form.

Liver of ſulphur from vitriolated tartar.

An explanation nearly ſimilar may be applied to th formation of liver of ſulphur, when vitriolated tarta is fuſed with an alkali and charcoal. Vitriolated tarta

Theory.

conſiſting of vegetable alkali united to vitriolic acid, is decompoſed by charcoal. This uniting with the vital air of the acid, at the ſame time that it communicates its phlogiſton to the baſe, converts the acid into ſulphur: the additional alkali ſerves only to aſſiſt the fuſion of the original maſs, and to prevent the diſſipation of the ſulphur by combining with it.

Antiphlogiſtic theory.

Thus far we have admitted the inflammable principle in our explanation; and it muſt be admitted, if it can be ſhewn that ſulphur contains it. We muſt confeſs however that this has not been proved; and that inflammable air has never been obtained directly from ſulphur, except a ſmall quantity, by paſſing ſteam of water over it when heated in an earthen tube *; in which caſe the original doubt preſents itſelf, whether the air come from the ſulphur or the water. The modern theory, which rejects phlogiſton, accounts for the preceding facts ſimply by the abſorption or extrication of vital air. Sulphur is taken to be a ſimple ſubſtance. The combuſtion of ſulphur conſiſts of the rapid combination of that ſubſtance with vital air; which, at the ſame time, gives out its heat as its capacity is diminiſhed. A ſmaller proportion of vital air, with the ſulphur, compoſes the volatile vitriolic acid, whether in the aerial form, or mixed with water: a larger doſe forms the complete vitriolic acid. If a combuſtible body be added to vitriolic acid, this body becomes burned, or calcined, by uniting with part of the vital air of the acid; the remainder conſequently has an over-proportion of ſulphur, and therefore becomes volatile. If the abſorption of pure air be ſufficiently

Page 95.

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* Prieſtley, VI. 150.

Theory.

ficiently copious, the acid is reſtored to its former ſtate, and becomes ſulphur again. When the combuſtible body is metallic, the pure air may, in ſome caſes, be driven out by heat from the reſidue. And laſtly, when inflammable air is obtained by the ſolution of metals in the diluted acids, it is taken for granted that it ariſes from the decompoſition of the water, whoſe vital air, uniting with the metal, conſidered as a principal ſubſtance, calcines it; while the inflammable part flies off, and the acid does nothing more than diſſolve the calx, and by that action facilitates its formation.

Detonation of hepatic air.

The detonation of hepatic with vital air may be readily explained on either hypotheſis; whether it be ſuppoſed to conſiſt chiefly, if not entirely, in the combuſtion of the ſulphur, which muſt by that means be ſuddenly converted into vitriolic acid air; or ſimply of the inflammable air, while the ſulphur is depoſited,

CHAP.

CHAP. II.

OF THE NITROUS ACID, ITS COMPONENT PARTS, AND COMBINATIONS.

NITROUS ACID.

Production of nitre.

THE nitrous acid is obtained from the ſalt called nitre or ſaltpetre, which conſiſts of the acid itſelf united to the vegetable alkali. This ſalt is never found in conſiderable quantities in nature, but is evidently produced by a concurrence of circumſtances. The nitrous acid appears to be produced in all ſituations where animal matters are completely decompoſed, with acceſs of air, and of proper ſubſtances with which it can readily combine. Grounds frequently trodden by cattle, and impregnated with their excrements; or the walls of inhabited places where putrid animal vapours abound, ſuch as ſlaughter-houſes, drains, or the like, afford nitre by long expoſure to the air.

Nitre beds.

Artificial nitre beds are made by an attention to the circumſtances in which this ſalt is produced by nature. Dry ditches are dug, and covered with ſheds, open at the ſides, to keep off the rain: theſe are filled with animal ſubſtances—ſuch as dung, or other excrements, with the remains of vegetables; and old mortar, or other looſe calcareous earth, this ſubſtance being found to be the beſt and moſt convenient receptacle for the acid to combine with. Occaſional watering, and turning up from time to time, are neceſſary to accelerate the proceſs, and increaſe the ſurfaces to which the air may apply. After a ſucceſſion of many months, more or leſs, according to the management of the operation,

NITROUS ACID.

nitre is found in the maſs. If the beds contained much vegetable matter, a conſiderable portion of the nitrous ſalt will be common ſaltpetre; but, if otherwiſe, the acid will, for the moſt part, be combined with the calcareous earth.

Extraction of ſaltpetre.

To extract the ſaltpetre from the maſs of earthy matter, a number of large caſks are prepared, with a cock at the bottom of each, and a quantity of ſtraw within, to prevent its being ſtopped up. In theſe the matter is put, together with wood-aſhes, either ſtrewed at top, or added during the filling. Boiling water is then poured on, and ſuffered to ſtand for ſome time; after which it is drawn off, and other water added in the ſame manner, as long as any ſaline matter can be thus extracted. The weak brine is heated, and paſſed through other tubs, until it becomes of conſiderable ſtrength. It is then carried to the boiler, and contains nitre and other ſalts; the chief of which is common culinary ſalt, or the marine acid united to the mineral alkali, or ſometimes to magneſia. It is the property of nitre to be much more ſoluble in hot than cold water; but common ſalt is ſoluble very nearly as much in cold as in hot water. Whenever, therefore, the evaporation is carried by boiling to a certain point, much of the common ſalt will fall to the bottom, for want of water to hold it in ſolution, though the nitre will remain ſuſpended by virtue of the heat. The common ſalt thus ſeparated is taken out with a perforated ladle; and a ſmall quantity of the fluid is cooled, from time to time, that its concentration may be known by the nitre which cryſtallizes in it. When the fluid is ſufficiently evaporated, it is taken out and cooled, and great part of the nitre ſeparates in cryſtals; while the remaining common ſalt continues diſſolved, becauſe equally ſoluble in cold as in hot water. Subſequent evaporation of the reſidue will ſeparate more nitre in the ſame manner.

Purification of nitre.

This nitre, which is called nitre of the firſt boiling, contains ſome common ſalt; from which it may be purified by ſolution in a ſmall quantity of water, and ſubſequent evaporation: for the cryſtals thus obtained are much leſs contaminated with common ſalt than before; becauſe the proportion of water is ſo much larger, with reſpect to the ſmall quantity contained by the nitre, that very little of it will cryſtallize. For nice purpoſes, the ſolution and cryſtallization of nitre are repeated four times. The cryſtals of nitre are uſually of a priſmatic form.

Decompoſition of nitre by heat.

If nitre be expoſed to a ſtrong heat, it melts, and becomes red hot; and the volatile product is found to conſiſt of fuming nitrous acid, a large quantity of vital air, and ſome phlogiſticated air; the alkali remaining behind, ſomewhat altered by a portion of the earth of the retort which it has diſſolved. Moſt other nitrous ſalts give out vital air by the ſame treatment. The extreme difficulty of aſcertaining the weights of aerial products, and of the fixed reſidues, renders it an embarraſſing taſk to ſhew by real experiment what happens in this operation among the principles of nitre.

Deflagration of nitre.

When a combuſtible body and nitre are brought into contact, either of them being previouſly heated red hot, the body is burned with great rapidity, no doubt by the vital air which the nitre affords by the heat; for the experiment ſucceeds in vacuo, and alſo when the bodies are ſurrounded by any aerial fluid incapable of maintaining combuſtion. This rapid combuſtion, effected by means of nitre, is called deflagration, when it is performed by a ſucceſſive burning of the parts of the body; or detonation, when the combuſtion of the whole is performed in ſo ſhort a time as to appear inſtantaneous. In this experiment it is remarkable that the combuſtion is maintained by vital air which is not in the elaſtic ſtate, but fixed in the nitre. Whence it ſhould follow, that either the vital air, or the combuſtible body, even in the fixed ſtate, has a great capacity for heat, of which it muſt contain a large quantity, on the hypotheſis of heat being matter. Or, if heat be a mere commotion, it will follow, that though the quantity of agitation produced by the ſudden coalition of particles, in the act of converting an elaſtic fluid into a denſe body, be ſuch as to produce a great effect in increaſing the temperature; yet the quantity is ſtill ſo conſiderable, when vital air and combuſtible matter unite even in their denſe ſtate, as to cauſe the moſt intenſe degree of ignition.

Detonation.

Invention of gunpowder.

This property of nitre has been applied to the production of a ſubſtance which has greatly affected the habits of human ſociety, particularly in thoſe wars which unfortunately their vices too often produce. The invention of gunpowder has totally changed the military ſyſtem of nations; and has probably ſuppreſſed much of that malice and inveterate rancour which actuate the minds of combatants who meet hand to hand, inſtead of managing the inſtruments of indiſcriminate ſlaughter at a diſtance. This deſtructive powder is compoſed of ſeventy-five parts by weight of

nitre,

Compoſition of gunpowder.

nitre, ſixteen of charcoal, and nine of ſulphur, intimately blended together by long pounding in wooden mortars, with a ſmall quantity of water. This proportion of the materials is the moſt effectual; but the circumſtance on which its effect more particularly depends is, the accurate mixture of the parts. Gunpowder is granulated by making the maſs into a ſtiff paſte, and agitating it upon a wire ſieve, which cuts it into ſmall parts; and theſe being ſhaken, or rolled in a barrel, take a rounded form by their mutual friction againſt each other. When any grain of a heap of gunpowder is ſet on fire, the detonation begins, and is propagated with amazing rapidity through the interſtices of the grains; a large quantity of permanently elaſtic fluid, conſiſting of one-third fixed air, and the reſt phlogiſticated air *, being at the ſame time produced. The expanſion of the elaſtic products is the cauſe of the well-known effects of gunpowder. It is ſaid that gunpowder is much weaker for being granulated. If the grains be pulverized, it is certain that the effect is much leſs, on account of the inflammation being propagated more ſlowly; but the aſſertion may nevertheleſs be true of powder which is newly made, and has never been grained. Gunpowder which has been ſuffered to become damp, ſcarcely ever recovers its former force; moſt probably becauſe the nitre, by a partial ſolution, becomes ſeparated from the maſs in more diſtinct ſaline cryſtals than before; and the wetting, which is neceſſary to the proceſs of granulating, may weaken the powder in the ſame way.

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* Berthollet, in the Mem. Acad. Par. 1781, page 231.

Fulminating powder.

When three parts by weight of nitre, two of mild vegetable alkali, and one of flowers of ſulphur, are rubbed together in a warm mortar, they compoſe a powder known by the name of fulminating powder. The effects of this powder, when fuſed in a ladle, and then ſet on fire, are aſtoniſhing. The whole of the melted fluid explodes with an intolerable noiſe; and the ladle is commonly disfigured, as if it had received a ſtrong concuſſion downwards. A drachm of the powder makes a report as loud as a cannon; but the noiſe of a few grains is ſufficiently unpleaſant in a room. It has very little effect, unleſs firſt melted. A mixture of liver of ſulphur with twice its weight of nitre, produces the ſame exploſion, though in leſs time; whence it appears that the alkali and ſulphur of the former preparation form a liver of ſulphur; and that the exploſion, in all probability, ariſes from the ſudden extrication of hepatic air from the liver of ſulphur; and vital air from the nitre, which burn the inſtant they are formed.

Diſtillation of nitrous acid.

If clay, bole, or alum, be mixed with nitre, and expoſed to diſtillation, the nitre is decompoſed, and the acid comes over; the attraction between itſelf and the alkali being weakened, partly by the attraction which the vitriolic acid uſually contained in thoſe bodies has for its alkali, and partly by the attraction exerted between the ſame alkali and the ſiliceous earth of the clay. If ſtrong vitriolic acid be added to nitre in a retort, the ſame decompoſition takes place with the application of much leſs heat, by virtue of the ſuperior attraction of the acid of vitriol to the alkaline baſe.

NITROUS ACID.

Nitrous acid is uſually yellow, and emits ſuffocating fumes of the ſame colour; but it may be rendered pure and colourleſs by a ſlight boiling in a retort. Aqua fortis is a weak ſpirit of nitre, and not remarkably pure. It uſually contains ſome marine acid.

The aſſayers purify their nitrous acid by adding a ſmall portion of the nitrous ſolution of ſilver. This metal unites with the marine acid it may contain, and falls down in the form of an inſoluble compound. Care muſt be taken to avoid adding too much.

Nitrous acid; with lime:

This acid, in combination with calcareous earth, forms a ſalt whoſe cryſtals deliqueſce by expoſure to the air. It is ſoluble in twice its weight of cold, or its own weight of boiling water. With ponderous earth, it forms a ſalt of difficult ſolubility. With magneſia it forms an acrid bitter ſalt, which is very ſoluble in water, and deliqueſcent in the air. With clay it forms an auſtere ſalt of difficult ſolution. None of theſe have yet been applied to any uſe.

—with ponderous earth; magneſia:

—and clay:

—with mineral alkali:

With the mineral alkali this acid forms a ſalt called quadrangular nitre, from the uſual form of its cryſtals. About three times its weight of water is required to hold it in ſolution in a mean temperature, and it is ſcarcely more ſoluble in hot water. Its properties reſemble thoſe of common nitre; but it is leſs fit for making gunpowder, becauſe it attracts the humidity of the air.

—with volatile alkali.

The nitrous acid, in combination with the volatile alkali, forms nitrous ammoniac; a ſalt which ſlightly attracts the humidity of the air, and is ſoluble in leſs than its own weight of water. If this ſalt be expoſed to heat in cloſed veſſels, it ſuddenly explodes; part of the acid and alkali is deſtroyed; and the aerial product is phlogiſticated air.

Production of nitrous acid.

Nitrous acid produced; by Mr. Cavendiſh:

—by M. Thouvenel.

Inference.

If a mixture of two parts by meaſure of vital air, obtained without the uſe of nitrous acid, and one of phlogiſticated air—or, which is the ſame thing, five parts of vital, and four of common air—be expoſed to the action of the electric ſpark in the upper part of a ſyphon, in which it may be confined by mercury; and a ſmall quantity of ſoap lees, or ſolution of pure vegetable alkali, be admitted into the cavity which contains the air; an abſorption will take place, and nitrous acid will be produced, as appears by the alkali being converted into true nitre. This is a ſlow operation, and requires the quantity of air in the ſyphon to be renewed very often, to ſupply the abſorption *. It has likewiſe been found that this acid is produced by expoſing vital air for a long time to the exhalations of putrifying animal ſubſtances, together with calcareous earth, or any other proper baſe to receive and combine with it †. There can be little doubt but the putrid exhalations conſiſted chiefly of phlogiſticated air. It appears therefore that this ſubſtance bears the ſame relation to the nitrous acid as ſulphur does to the vitriolic. As ſulphur by combuſtion, in which vital air is an indiſpenſable requiſite, becomes converted into vitriolic acid, ſo phlogiſticated air becomes converted into nitrous acid; though, on

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* For the detail of the particulars of this moſt curious experiment, conſult Mr. Cavendiſh's papers, in the Phil. Tranſ. Vol. LXXV. p. 372; and Vol. LXXVIII. p. 255.

† This is the diſcovery of M. Thouvenel. See his Prize Diſſertation on the Formation of Nitre.

account

NITROUS ACID.

account of its being leſs combuſtible, the red heat cannot be produced and kept up without the co-operation of electricity: and as ſulphur, when in contact with the pure air of the atmoſphere, and with a baſe proper for combining with the vitriolic acid, is converted into that acid by a ſlow combuſtion in the pyrites; ſo the like expoſure of phlogiſticated air, in contact with calcareous earth, to vital air, produces nitrous acid, though much more ſlowly, becauſe the baſe is leſs combuſtible.

Nitrous acid with combuſtible matter.

The nitrous acid acts with peculiar energy on combuſtible ſubſtances, which it burns or calcines; and during moſt of theſe proceſſes a peculiar kind of air flies off, which is called nitrous air. It is produced by the ſolution of many of the metals, by moſt vegetable, and ſome animal ſubſtances. This aërial fluid is not rapidly imbibed by water, and may therefore for temporary uſe be received over it. It is not heavier than common air; and poſſeſſes the remarkable property of ſuddenly uniting with vital air, with which it forms nitrous acid. The mixture of theſe two kinds of air forms a red cloud, which is imbibed by the water, and renders it acid, if the experiment be performed over that fluid; and, from examination of this acid water, it is proved that the cloud is the nitrous acid itſelf. From this circumſtance Dr. Prieſtley inſtituted a method of determining the purity or reſpirability of the air of the atmoſphere, or any other permanently elaſtic fluid. He found, by a variety of experiments, that when nitrous air and any other air are mixed, they undergo no change, if the latter be totally unfit to ſupport combuſtion or animal life; but, if the

Nitrous air, p. 94.

Dr Prieſtley's method of aſcertaining the reſpirability of air.

the contrary, the red cloud is formed; and the whole bulk of the mixture is diminiſhed by a quantity which is ſo much the greater, accordingly as the air in queſtion is of a quality more ſuited to thoſe purpoſes. This diminution he likewiſe proved to conſiſt of a proportional part of the air which is tried, together with as much of the nitrous air as is required to produce the effect; ſo that, if the nitrous air be duly proportioned to the effect, it will wholly diſappear.

Imperfections of the trial of air by nitrous air.

The trial of the purity of common air by means of nitrous air, has not however been found to exhibit ſuch remarkable differences between the air taken up at various places as their known ſalubrity or unhealthineſs might have given reaſon to expect. Two reaſons may be offered to account for this. The firſt is, that a ſmall difference in the purity of the air of a place may have a very conſiderable effect on the health of thoſe who are obliged to breathe it for a long ſucceſſion of time: the ſecond is, that, the effects of nitrous air being the ſame upon elaſtic fluids which contain equal proportions of vital air, however greatly their other component parts may differ in their properties, it will only be ſhewn that the airs are equally ſalubrious, as far as depends on their proportion of vital air, though they may by no means be ſo with regard to their noxious parts.

Eudiometers.

There are ſeveral ingenious contrivances, called eudiometers, for the mixing of nitrous and other air, and meaſuring their diminution. As theſe however are not eaſily procured, and more eſpecially as Dr. Prieſtley, whoſe experience is greater than that of any other philoſopher, uſes a ſimple tube, it does not ſeem neceſſary to deſcribe them here. The doctor's method is as follows:

Dr. Prieſtley's method of aſcertaining the purity of air.

He firſt provides * a phial containing about an ounce of water, which he calls the air meaſure. This he fills with air, by having firſt filled it with water, and placed it over the opening of the funnel, in his ſhelf (fig. 15); and when it is filled, he ſlides it along the ſhelf, always obſerving that there be a little more air than is wanted. The phial being thus exactly filled with the air he is about to examine, and care being taken that it be not warmed by holding in the hand, he empties it into a jar of about an inch and a half in diameter; and then introduces to it the ſame meaſure of nitrous air, and lets them continue together about two minutes. The Doctor chooſes to have an overplus of nitrous air, that he may be ſure that its effect may be the utmoſt poſſible. If he finds the diminution of theſe two meaſures to be very conſiderable, he introduces another meaſure of nitrous air; but the pureſt vital air will not, he believes, require more than two meaſures of nitrous air.

Sometimes he leaves the common and nitrous air in the jar all night, or a whole day; but he always takes care, whenever he compares two kinds of air, that both ſhall remain the ſame length of time in the veſſels, before he notes the degree of diminution.

When the preceding part of the proceſs is over, he transfers the air into a glaſs tube, about three feet long, and one third of an inch wide, carefully graduated according to the air meaſure, and divided into tenth and

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* Prieſtley, IV. p. 30. I give the account nearly in his words.

hundredth parts; ſo that one of the hundredth parts will be about a ſixth or an eighth of an inch. Then immerſing the tube in a trough of water, ſo that the water in the inſide of the tube ſhall be on a level with the water on the outſide, he obſerves the ſpace occupied by the aerial mixture; and expreſſes the reſult in meaſures and decimal parts of a meaſure, according to the graduation of the tube.

Eudiometer tube.

It is ſome trouble to graduate a tube in this manner; but when it is once done, the application of it is extremely eaſy. As it ſeldom happens that a glaſs tube is of an equal diameter throughout, the Doctor generally fills that part of the tube which contains one meaſure with quickſilver; and then weighing it and dividing it into ten parts, he puts them in ſeparately, in order to mark the primary diviſions. The weighing is rendered very eaſy by the help of a glaſs tube, drawn to a fine orifice, which ſerves to take up a ſmall quantity at a time, as may be required in making the adjuſtment.

Page 92.

It has been already obſerved that common air loſes about one fourth of its bulk by any proceſs equivalent to combuſtion. This alſo happens when it is mixed with nitrous air.

Action of nitrous acid on animal ſubſtances.

When the nitrous acid acts upon the fleſh, or other parts of animal ſubſtances, the elaſtic fluid which is firſt and moſt plentifully diſengaged is phlogiſticated air. In this experiment the phlogiſticated air may come from the animal ſubſtance, or the acid, or both; ſince both contain it. It appears however to be much more probable that the whole comes from the animal ſubſtances; for it is afforded by the application of a very weak nitrous acid, at ſo low a temperature as 65° or 70°; both which circumſtances do not appear to indicate a decompoſition of the acid. The nitrous acid, after its action, ſaturates as large a quantity of alkali as before*. The quantity of phlogiſticated air is in proportion to the quantity of volatile alkali which the animal ſubſtance made uſe of affords by diſtillation: and it is known that the quantity of phlogiſticated air contained in any animal ſubſtance muſt be in this proportion. And, laſtly, at a greater heat, after the phlogiſticated air has come over, there is a diſengagement of nitrous air, which indicates a leſs complete decompoſition of the acid than that which would have afforded phlogiſticated air: and it is not conſonant with other chemical facts, that the complete decompoſition of the acid ſhould happen at a lower heat than the partial decompoſition which ſucceeds it.

Page 124.

Various fluids imbibe nitrous air.

Water will imbibe about one tenth of its bulk of nitrous air, which, if immediately expelled by heat, is not found to be changed in its properties. The reſiduum which is not imbibed is phlogiſticated air. The vitriolic acid abſorbs nitrous air, and aſſumes a purple colour. The marine acid imbibes it, and becomes blue. Ether, alkaline liquors, and ſpirit of wine, alſo abſorb it.

Diminution of nitrous air by electricity, &c.

The electric ſpark diminiſhes nitrous air about one half, and converts it into phlogiſticated air, at the ſame time that acid is depoſited. Iron filings and brimſtone, liver of ſulphur, or iron alone, being expoſed to nitrous air, diminiſh it, and convert it into phlogiſticated air. But the moſt ſingular circumſtance in theſe proceſſes is, that, though they are of the nature of combuſtion, and do in the end render air perfectly unfit for maintaining it, yet, at a certain period before this, the air is put into a ſtate in which a candle burns in it better than in common air, though it ſtill continues perfectly deſtructive of animal life. Dr. Prieſtley calls this dephlogiſticated nitrous air.

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* The quantity of alkali ſaturated by any acid being different according to the ſtate of the acid, with regard to what is called phlogiſtication, this proof cannot be admitted as abſolutely concluſive, unleſs the ſame quantity of true nitre be formed in both caſes. I do not find whether this has or has not been done. See Annales de Chimie, I. 42.

Dephlogiſticated nitrous air.

Abſorption of nitrous air by the nitrous acid.

If nitrous acid be expoſed to nitrous air, the latter is abſorbed in large quantities; and the colour of the acid changes firſt at the ſurface, and gradually through the whole of the liquid: the ſucceſſions of colour are, firſt yellow, then deep orange, next green, and laſtly blue, according to the quantities of nitrous air abſorbed. This abſorption renders the acid much more volatile. Hence it appears that the various colours of nitrous acid are owing to its having abſorbed nitrous air, which continually eſcaping, and combining with the vital air of the atmoſphere, forms the yellow or reddiſh fumes it uſually emits when in an open veſſel.

Pale nitrous acid, becomes yellow:

The pale or dephlogiſticated nitrous acid, if expoſed to the action of light, gives out pure air, and itſelf becomes yellow and fuming. Heat alſo produces the ſame effect. The nitrous acid itſelf appears to be capable of ſubſiſting in the aerial form, though its power of combining with water, mercury, or any other fluid uſed for confining it, prevents experiment from being made upon it with the ſame facility as

— is capable of the elaſtic form.

with other kinds of air. Water impregnated with this air or vapour becomes ſucceſſively blue, green, and at laſt yellow, when it has received an increaſe of one third of its bulk. This water emits a great quantity of nitrous air, and does not ſeem to differ eſſentially from pure nitrous acid which has imbibed nitrous air.

Inflammation of eſſential oils by nitrous acid;

One of the earlieſt known facts of ſpontaneous inflammation is that produced by the affuſion of the nitrous acid upon oil. All the oils obtained by diſtillation from vegetables, and known by the name of eſſential oils, are proper for this experiment. An ounce of the oil intended to be ſet on fire muſt be placed in a ſhallow veſſel, and a bottle containing an ounce of the moſt concentrated nitrous acid muſt be faſtened at the end of a pole, that the operator may be ſufficiently diſtant from the inflammation. Two thirds of the acid being poured on the oil, makes a conſiderable ebullition; the oil growing black and thick, and ſometimes taking fire. But if this laſt circumſtance does not happen in five or ſix ſeconds, the remainder of the acid muſt be poured where the mixture appears moſt dry and black; and then the inflammation ſeldom fails to take place.

— of fat oils:

Fat oils may alſo be inflamed, if equal parts of the nitrous and vitriolic acids be firſt poured on them, and, when the ebullition is at the greateſt, a portion of nitrous acid be poured on the drieſt part.

—of charcoal, or lamp black.

Strong nitrous acid, of the ſpecific gravity of 1.54, being added to the powder of charcoal, or lamp black*, recently made very dry, takes fire, and detonates.

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* Prouſt in the Journal de Medecine, for July 1778.

nates. There is ſome uncertainty in this experiment; but the method which is ſaid to enſure ſucceſs, is, to put the dry powder into a very dry retort, and pour the acid upon the ſide of the glaſs, ſo that it may not fall upon the powder, but flow beneath it.

The production of heat in theſe phenomena, which doubtleſs ariſes from the action exerted between the combuſtible body and the vital air of the acid, has not yet been explained in an adequate manner from experiments, tending to ſhew how the capacities of the bodies are changed by the proceſs.

Recapitulation and theory.

On a review of the facts in the foregoing chapter, it will not be difficult to apply in a general way the ſame theories as were exhibited in treating of the vitriolic acid. The preparation of nitre beds conſiſts ſimply in a proceſs by which the exhalations of putrid ſubſtances may combine with vital air, and the product be received into a combination with calcareous earth, or with the alkali of decayed vegetables; and the ſubſequent manipulations are the mere application of water, to ſeparate the ſeveral matters from each other according to their reſpective degrees of ſolubility. That nitrous acid contains vital air, is evident from the diſtillation of nitre without addition; and that in the acid it is applied to, or combined with, phlogiſticated air, appears equally clear from the * experiment of Mr. Cavendiſh, and from the frequent appearance of this aerial ſubſtance in experiments with nitrous air. The queſtion in this proceſs therefore ſeems to be, whether the air called phlogiſticated air do really

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* Phil. Tranſ. quoted, page 152.

contain

NITROUS ACID.

contain an inflammable principle, which it gives out during combination with the vital air; or whether it ſimply unite to this laſt? Upon the former ſuppoſition, the theory of the general facts will be as follows:

Theory.

Nitrous acid conſiſts of vital air united to a certain proportion of phlogiſticated air, which has been deprived of phlogiſton during combination. When a combuſtible body is preſented to this acid, it becomes corroded or burned; that is to ſay, it combines with ſome of the vital air, and parts with ſome of its own phlogiſton. In this ſtate the acid is no longer the ſame; for it has loſt vital air, and part of its phlogiſticated air has regained phlogiſton. It therefore emits either nitrous air, which is an imperfect nitrous acid, wherein the phlogiſton is too abundant, and the vital air too deficient, to exhibit acid properties; which on that account readily abſorbs vital air, and is by that means precipitated again in the original acid form: or, if the decompoſition be more completely made, the quantity of vital air abſorbed, and of phlogiſton emitted, by the combuſtible body, may be ſuch as that only phlogiſticated air ſhall be extricated, as is the caſe with animal ſubſtances. Again, the compoſition of nitrous air being thus eſtabliſhed, if the electric ſpark be applied to produce ignition in this aerial fluid, the ſmall portion of vital air intimately unites with as much of the phlogiſticated air as is required to form nitrous acid, and leaves the reſidue of phlogiſticated air behind: or, if any proceſs of ſlow combuſtion be carried on in it, the whole of the vital air is abſorbed, and as much phlogiſton extricated as converts the reſidue into phlogiſticated air. It is evident that the

Page 159.

Page 162.

Page 163.

Ibid.

Page 164.

abſorp-

NITROUS ACID.

abſorption of nitrous air muſt equally alter the proportions of the component parts of the nitrous acid, and produce ſimilar effects.

The ſingular properties of the air called dephlogiſticated nitrous air have not been ſatisfactorily explained upon any theory.

Theory:

— of the antiphlogiſtians.

It is obvious that the explanation of theſe events may be made at leaſt with equal facility according to the other theory. Phlogiſticated air and vital air are applied to each other under certain circumſtances, and nitrous acid is produced. Hence it is concluded that theſe aerial ſubſtances have united together, and are the component parts of nitrous acid. When an inflammable ſubſtance is burned, or a metal calcined, by the action of this acid, one of its component parts, namely, vital air, unites with the body; and the ſurplus of the other principle, namely, phlogiſticated air, flies off either alone, or in combination with a ſufficient portion of vital air to form nitrous air. The addition of vital air to this laſt aerial product completely forms nitrous acid; the ſubtraction of the vital air it poſſeſſes muſt change it into phlogiſticated air.

Action of light.

The phenomenon of nitrous acid becoming yellow and fuming by the action of light or heat, will ſhew that it receives phlogiſton, according to the ancient hypotheſis. As it ſeems however to be a bold ſuppoſition, that either light or heat, conſidered as matter, can transfer the inflammable principle through glaſs veſſels, the fact has been more ingeniouſly explained by recourſe to the decompoſition of water. It is aſſerted that the nitrous acid attracts the inflammable air, or phlogiſton, of the water, and ſets its vital air at liberty.

NITROUS ACID. Theory.

liberty. According to the antiphlogiſtic theory, it is ſimply ſaid that heat or light expels part of the vital air from the nitrous acid, as the event ſhews; and that the reſidue, having an over-proportion of phlogiſticated air, is of courſe coloured and fuming.

The reader may eaſily apply theſe theories to the combuſtion of oils or charcoal by the nitrous acid, as far as the facts can be clearly ſtated, or are known: for theſe are doubtleſs of the ſame nature as other combuſtions.

Keir's compound acid. See Chap. II. Book II.

It is a late diſcovery of Mr. Keir[*], that a mixture of the concentrated vitriolic and nitrous acids forms a ſolvent peculiarly calculated to diſſolve ſilver in a large proportion; though it has ſcarcely any efficacy in ſuſpending any other metallic ſubſtance. He forms it by diſſolving nitre in concentrated vitriolic acid. Tin, mercury, and nickel, are acted upon, and chiefly calcined, by this compound acid; the latter being diſſolved in a ſmall quantity: but it has little or no action upon the other metals. Dilution with water renders it leſs capable of diſſolving ſilver, but more active with regard to the other metals.

If this acid be digeſted upon ſulphur, it undergoes the change called phlogiſtication, and emits nitrous fumes; the nitrous acid probably loſing its acidity in proportion as the ſulphur becomes acidified. Its affinities, or ſolvent powers, are conſiderably changed by this proceſs. The ſame phlogiſticated acid is afforded, if the nitrous vapour or air be added to vitriolic acid, inſtead of common nitre; or if nitre with baſis of volatile alkali be uſed.

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[*] Phil. Tranſ. Vol. LXXX. p. 373.

CHAP.

CHAP. III.

OF THE MARINE ACID AND ITS COMBINATIONS, INCLUDING AQUA REGIA.

COMMON SALT.

Salt mines and ſprings.

Sea water.

THE marine acid is obtained from common culinary ſalt, in which it is united to the mineral alkali. Common ſalt is found in large maſſes, or in rocks, under the earth, in England and elſewhere. There are alſo many ſalt ſprings in various parts of the world; and the waters of the ocean every where abound with it, though in different proportions. The water of the Baltic ſea * is ſaid to contain one ſixty-fourth of its weight of ſalt; that of the ſea between England and Flanders contains one thirty-ſecond part; that on the coaſts of Spain one ſixteenth part; and between the tropics it is ſaid, perhaps erroneouſly, to contain from one eleventh to one eighth part.

Extraction of common ſalt from waters.

The whole art of extracting ſalt from waters which contain it, conſiſts in evaporating the water in the cheapeſt and moſt convenient manner. In England, a brine compoſed of ſea water, with the addition of rock ſalt, is evaporated in large ſhallow iron boilers; and the cryſtals of ſalt are taken out in baſkets. In Ruſſia, and probably in other northern countries, the ſea water is expoſed to freeze; and the ice, which is almoſt entirely freſh, being taken out, the remaining brine is much ſtronger, and is evaporated by boil-

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* Rome de l'Iſle's Cryſtallographie, Vol. I. p. 375, quoted by Magellan in his improved edition of Cronſtedt, p. 360.

ing. In the ſouthern parts of Europe the ſalt-makers take advantage of ſpontaneous evaporation. A flat piece of ground near the ſea is choſen, and banked round, to prevent its being overflowed at high water. The ſpace within the banks is divided by low walls into ſeveral compartments, which ſucceſſively communicate with each other. At flood tide, the firſt of theſe is filled with ſea water; which, by remaining a certain time, depoſits its impurities, and loſes part of its aqueous fluid. The reſidue is then ſuffered to run into the next compartment; and the former is again filled as before. From the ſecond compartment, after a due time, the water is transferred into a third, which is lined with clay, well rammed, and levelled. At this period the evaporation is uſually brought to that degree, that a cruſt of ſalt is formed on the ſurface of the water, which the workmen break, and it immediately falls to the bottom. They continue to do this until the quantity is ſufficient to be raked out, and dried in heaps. This is called bay ſalt.

Various methods —of obtaining ſalt. — from the waters

In ſome parts of France, and alſo on the coaſts of China, they waſh the dried ſands of the ſea with a ſmall proportion of water, and evaporate this brine in leaden boilers.

— of the ſea

At ſeveral places in Germany, and at Montmarot in France, the waters of ſalt ſprings are pumped up to a large reſervoir at the top of a building or ſhed; from which it drops or trickles through ſmall apertures upon boards covered with bruſh wood. The large ſurface of the water thus expoſed to the air, cauſes a very conſiderable evaporation; and the brine is afterwards conveyed

— and ſalt ſprings.

veyed to the boilers for the perfect ſeparation of the ſalt.

Salts contained in the ſea.

The water of the ſea contains, beſides the common ſalt, a conſiderable proportion of magneſian marine ſalt, and ſome gypſum, or lime combined with vitriolic acid. The magneſian ſalt is the chief ingredient of the remaining liquid which is left after the extraction of the common ſalt, and is called the mother water. Sea water, if taken up near the ſurface, contains alſo the putrid remains of animal ſubſtances, which render it nauſeous, and in long continued calms cauſe the ſea to ſtink.

Cryſtallization of common ſalt.

The cryſtals of common ſalt are right-angled ſix-ſided ſolids, and are uſually ſaid to be cubes. Theſe form at the ſurface, where the evaporation is the greateſt; and they float by virtue of the repulſive power of their dry upper ſurfaces, which diſplaces a quantity of the ſurrounding water: a circumſtance common to all ſuch ſmall bodies as are not eaſily wetted. When the cryſtal becomes too large to be ſuſpended in this way, it ſinks. If two floating cryſtals come ſo near each other as that the hollow ſpaces may communicate, they fall together into one cavity at the ſurface, without ſinking; and the ſucceſſive appoſition of other cryſtals often produces a curious hollow pyramid, which is ſquare, becauſe the figure of the cryſtals themſelves occaſions them to apply to each other only in the poſition required to produce ſuch a ſolid.

Common ſalt does not alter in the air; but when expoſed to heat, it cracks and flies in pieces, by the

MARINE ACID.

eſcape of its water of cryſtallization. A greater heat ignites and melts it; and a ſtill greater cauſes it to riſe totally in white fumes. The action of ſea ſalt upon earths is not conſiderable. It aſſiſts the fuſion of ſiliceous earth; and is thrown into the furnace wherein the pottery called ſtone-ware is baked, where it riſes in fumes, and glazes their ſurface; probably by the combination of its alkali with the ſiliceous earth contained in the clay. The decompoſition of ſea ſalt by litharge has already been mentioned in treating of the mineral alkali. Page 118.

Diſtillation of marine acid from common ſalt.

The marine acid may be obtained from common ſalt by proceſſes ſimilar to thoſe deſcribed for procuring the nitrous acid in the preceding chapter. The moſt effectual and elegant way conſiſts in applying one part by weight of ſtrong vitriolic acid to three of decrepitated ſea ſalt, in a retort whoſe upper part is furniſhed with a tube or neck, through which the acid is to be poured upon the ſalt. The aperture of this tube muſt be immediately cloſed with a ground ſtopper after the pouring. The vitriolic acid immediately combines with the alkali, and expels the marine acid in the form of a peculiar air; which is rapidly abſorbed by water, but may be confined by mercury. As this combination and diſengagement take place without the application of heat, and the aerial fluid eſcapes very readily, it is neceſſary to arrange and lute the veſſels together before the vitriolic acid is added, and not to make any fire in the furnace until the diſengagement begins to ſlacken; at which time it muſt be very gradually raiſed. Before the modern improvements in chemiſtry were made, a great part of the

Marine acid air.

Diſtillation.

the acid eſcaped, for want of water to combine with; but by the uſe of the apparatus, fig. 21 or 22 (or a combination of veſſels equivalent to both of them), the acid air is made to paſs through water, in which it is condenſed, and forms marine acid of double the weight of the water, though the bulk of this fluid is increaſed one half only. The acid condenſed in the firſt receiver, which contains no water, is of a yellow colour, ariſing from the impurities of the ſalt.

Marine acid air:

Heat expels the marine acid air from marine acid, and leaves the water behind. The fumes of ſpirit of ſalt conſiſt of this air in the act of uniting with the watery vapours of the atmoſphere, which render it viſible. This air has nearly the ſame affinities as the acid itſelf in the fluid form. The electric exploſion diminiſhes it a little; but the remainder is almoſt totally ſoluble in water as before.

— its corroſive nature.

It is an object of conſiderable importance to the practical chemiſt, to be aware of the corroſive nature of this acid air. If the proceſſes in which it is ſet at liberty be carried on in a room where balances and other metallic inſtruments are kept, though the quantities may not be perceptible by the ſmell or otherwiſe, yet the inſtruments will in the courſe of a few days be covered with ruſt. It is indeed by no means prudent to keep, or make uſe of, any delicate metallic inſtruments in the ſame apartment which is appropriated to chemical proceſſes.

Salt of Sylvius.

The marine acid, in combination with the vegetable alkali, forms a ſalt called ſalt of Sylvius, or, improperly, regenerated ſea ſalt. It is of a bitter taſte, ſlightly deliqueſcent, and ſoluble in about three times its weight of water. This is ſometimes uſed in medicine.

MARINE ACID.

Sal ammoniac.

With the volatile alkali it forms common ſal ammoniac, which is a conſiſtent ſalt, of a ſharp briny taſte; and ſo remarkably deficient in the uſual brittleneſs of this claſs of bodies, that it is not eaſily pulverized. It is ſoluble in between three and four times its weight of water, in a common temperature. By heat it ſublimes entire in cloſed veſſels.

Marine ſelenite.

The ſaline combination of lime with marine acid is ſometimes called marine ſelenite, and ſometimes fixed ammoniac; becauſe it forms the fixed reſidue after ſal ammoniac has been expoſed to diſtillation with lime. This ſalt may be obtained in the form of cryſtals, but it deliqueſces with air. It is ſoluble in leſs than twice its weight of cold water. The combination of lime and marine acid which remains after diſtilling ſal ammoniac, has uſually an over-proportion of lime. If it be urged by a violent heat, it fuſes; and when cold, it has the property of emitting a phoſphoric light upon being ſtruck with any hard body. Hence it is called Homberg's phoſphorus, from the name of the firſt obſerver.

Homberg's phoſphorus.

Argillaceous marine ſalt.

The argillaceous marine ſalt has a gelatinous conſiſtence when diſſolved in a ſmall quantity of water. Its taſte is ſtyptic, and it affords cryſtals by ſpontaneous evaporation.

Ponderous marine ſalt.

The combination of ponderous earth with marine acid forms a cryſtallizable ſalt of difficult ſolution. Its ſolution is of admirable uſe for detecting the preſence of the vitriolic acid in any fluid; becauſe this air combines with the earth, and forms an inſoluble precipitate of ponderous ſpar. It is more eſpecially uſeful for purifying the marine acid itſelf from the vitriolic acid, which it often contains. The exact quantity of ſolution neceſſary to be added for this purpoſe to any veſſel of marine acid, may be known by previous trials with ſmall portions of the acid.

Magneſian marine ſalt.

Magneſian marine ſalt exiſts in all ſalt waters. It is ſoluble in leſs than its own weight of water; and cannot be obtained in the cryſtalline form but by firſt evaporating its ſolution, and then ſuddenly expoſing it to a great degree of cold. It is the cauſe of the bitterneſs of ſea water; and, like moſt of the other ſalts laſt deſcribed, it is applied to no uſeful purpoſe.

Action of marine acid upon metals.

The marine acid has ſcarcely any action upon combuſtible ſubſtances in general. It acts directly upon tin, lead, copper, iron, zinc, biſmuth, antimony, manganeſe, arſenic; but does not affect gold, ſilver, platina, mercury, wolfram, or cobalt.

Dephlogiſticated or aerated marine acid.

If the marine acid be diſtilled from about one fourth of its weight of the black calx of manganeſe, a ſuffocating elaſtic fluid ariſes, which corrodes mercury, and is abſorbed by water. The impregnation of water with this fluid (which was named the dephlogiſticated marine acid by its diſcoverer SCHEELE) may be conveniently performed by means of the apparatus, fig. 21 *. If the concentrated marine acid be uſed, the diſengagement takes place without heat; but if it be weaker, the application of a gentle heat is neceſſary. The common marine acid which may riſe is condenſed in the firſt bottle; and the dephlogiſticated acid unites to

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* Berthollet, in the Mem. Acad. Par. for 1785; and in Rozier's Journal for Sept. 1788.

MARINE ACID.

Dephlogiſticated or aerated marine acid.

the water in the ſecond; the water, as it becomes ſaturated, aſſumes a greeniſh yellow colour. When the ſaturation is complete, the dephlogiſticated acid takes concrete form, and deſcends to the bottom in yellowiſh flocks, provided the temperature of the water be only a few degrees above freezing. An increaſe of temperature, ſuch as may be produced by applying the hand to the veſſel, cauſes this concrete matter to aſſume the aerial form, and eſcape in bubbles to the ſurface. The taſte of the ſolution is auſtere, but does not reſemble that of acids. It combines with fixed alkalis without cauſing them to give out their fixed air, if they be in a mild ſtate. Heated with lime, or fixed alkali, it emits vital air, and then forms the ſame ſaline combinations as the common marine acid would have done. It diſſolves all metals directly, without affording inflammable air, as the marine acid does with ſome of them; and its ſaline combinations are, for the moſt part, the ſame as the common acid produces when made to combine with thoſe bodies. It deſtroys vegetable colours, rendering them white without firſt cauſing them to become red; it bleaches wax; and in general produces immediately, in a variety of ſubſtances, the ſame changes as are effected by long expoſure to air. This property has already been applied with ſucceſs in manufactories.

Annales de Chimie, II. 151—190.

Salt into which dephlogiſticated marine acid enters.

When the aeriform dephlogiſticated marine acid is received in a ſolution of pure vegetable alkali, and the liquor evaporated, two kinds of ſalt are obtained. The one is the common ſalt of Sylvius, which ſeparates from the fluid as the evaporation goes on; and the other is a ſalt which, being more ſoluble in hot

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Detonating marine ſalt; with baſe of vegetable alkali:

than in cold water, affords cryſtals by cooling. Theſe are of a long rhomboidal figure, and a ſilvery brilliancy; have an inſipid cooling taſte, reſembling nitre; do not deliqueſce in the air; and detonate with charcoal, or with iron, more ſtrongly than nitre itſelf does. By heat alone they give out vital air; and the reſidue of their detonation with charcoal is the ſalt of Sylvius. Hence it is obvious that a portion of the alkali has imbibed ſome of the dephlogiſticated marine acid, together with the overplus of vital air contained in a great part of the reſt of the acid; and that this alkali forms the preſent ſalt; while the acid which was deprived of the overplus, and by that means reduced to the common ſtate, forms the ſalt of Sylvius, which is in much the greateſt proportion in the ſolution.

— with mineral alkali:

If the mineral alkali be uſed, a ſalt nearly of the ſame nature is formed; but too deliqueſcent to afford cryſtals.

—volatile alkali.

Volatile alkali is decompoſed by the dephlogiſticated marine acid; the vital air combining with its inflammable part, and the phlogiſticated air flying off.

Action of light.

When the ſolution of dephlogiſticated marine acid is expoſed to the action of light, it emits vital air, and becomes converted into common marine acid.

Theory.

When we reaſon by analogy from the vitriolic and nitrous to the marine acids, we muſt conclude that this laſt conſiſts of a baſe of a combuſtible nature united to vital air. And as the greater combuſtibility of ſulphur, the baſe of the vitriolic acid, when compared with phlogiſticated air, or the baſe of nitrous acid, appears to be the cauſe why the action of the latter is more generally effectual upon combuſtible bodies,

Theory.

bodies, to which it can with more facility transfer its vital air, and probably receive phlogiſton from them at the ſame time; ſo the baſe of marine acid, being apparently leſs combuſtible than even that of the nitrous, may, in its ordinary ſtate of acidity, hold too ſmall a quantity of vital air, or too large a proportion of phlogiſton, to act with energy on other combuſtible bodies. But whenever it is combined with a ſurplus of vital air from the calx of manganeſe (which certainly contains it, becauſe it affords it by ſimple heat), it muſt act with great effect on bodies which are diſpoſed to combine with that principle, for the ſame reaſon as the nitrous acid does; namely, becauſe it is eaſily decompoſed. And this reaſon will in fact be the ſame, whether the action of acids be conſidered according to the modern theory, as conſiſting chiefly in the combination of vital air with the combuſtible body; or whether this laſt be ſuppoſed in the old theory to afford phlogiſton to the baſe, or other component part, of the acid.

Action on combuſtible bodies.

It muſt be confeſſed however that the general circumſtances attending the change which the marine acid ſuffers by the acceſſion of vital air, are not ſtrictly conſonant throughout with what happens to the other acids. The phlogiſticated vitriolic and nitrous acids are rendered more acid by the addition of vital air, which is generally admitted to be the chief principle of acidity. The marine acid, on the contrary, has its activity increaſed, by ſuch an addition or change, only with reſpect to combuſtible bodies; but is leſs active on the alkalis and earths, inſomuch that ſome writers have thought it might be denied to be an acid.

Acidity of marine acid does not vary after the law of other acids.

AQUA REGIA.
Theory.

acid. From this inſtance acidity appears to have its limits, ſo as to conſiſt of a preciſe term of dephlogiſtication, or of ſaturation with vital air; and to be impaired or deſtroyed by an exceſs either way. A full and adequate explanation of the changes of the marine acid cannot but afford much advantage to the general theory of acids, which occupy ſo large a ſpace among the objects of chemical inquiry.

Compoſition of aqua regia:

When one or two parts of pale concentrated nitrous acid are mixed with four parts of fuming marine acid, an effervescence ſoon takes place *, and dephlogiſticated marine acid flies off in the aerial form, at the ſame time that the mixture becomes of a deep red colour. The mixed acid is called aqua regia; and has been long remarkable for its property of diſſolving gold, which is not ſenſibly acted upon by either of the acids that compoſe it.

—otherwiſe.

Aqua regia may be made by adding to nitrous acid any ſalt which contains the marine acid: for the affinity of the nitrous acid to the baſe being in moſt caſes ſtronger than that of the marine, this laſt is ſet at liberty; and conſequently the mixture, if the ſalt be not exceſſive in quantity, will contain the acids in a diſengaged ſtate. An aqua regia will therefore be produced, which is not eſſentially impaired with reſpect to common uſes by the portion of ſalt it may hold in ſolution. It is uſual to make aqua regia by diſſolving ſal ammoniac in about four times its weight of ſtrong nitrous acid; but the reſults

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* Berthollet, in Acad. Par. 1785.

of experiments or operations muſt vary conſiderably according to the proportion and the ingredients made uſe of.

The effects and theory of aqua regia.

The nature of this mixed acid has not yet been clearly aſcertained. After the diſcovery of the dephlogiſticated marine acid, it was concluded, that the nitrous acid performed the ſame office as the manganeſe does; that is, in fact, that it either deprives the marine acid of phlogiſton, or affords vital air to combine with it, or both. Several difficulties however oppoſe this ſuppoſition. If the marine acid be enabled to calcine and diſſolve gold becauſe it has been dephlogiſticated or aerated by the nitrous acid, it ſhould follow much more ſtrongly that the nitrous acid itſelf ſhould diſſolve that metal, which is contrary to the fact. And, again, it has not been ſhewn how this dephlogiſticated acid, which is ſo volatile, and ſo ſparingly ſoluble in water, is retained in the ſolution: not to mention that no component part of the nitrous acid is found to eſcape during the efferveſcence, except the vital air which enters into the compoſition of the gas that flies off. When the two acids are in due proportion, therefore, aqua regia muſt conſiſt of marine acid, and nitrous acid which has an under-proportion of vital air, or is in the moſt fuming ſtate; or, in other words, it contains the two baſes of the acids, together with vital air, leſs in quantity than they poſſeſſed in their ſeparated ſtate. But, whether theſe principles combine and form a compound acid, or in what other order they may be arranged, has not yet been experimentally determined; though the writings of chemiſts abound with conjectural inferences reſpecting them.

The

AQUA REGIA.
Combinations.

The combinations of earths and alkalis, and even of metals, with aqua regia, have not been well examined. It is not known whether two different kinds of ſalts are formed apart from each other, or whether a triple combination takes place conſiſting of two acids united to one baſe. It appears however that in ſome caſes the reſult is one entire compound, and in others two ſeparate ones.

CHAP. IV.

OF FIXED AIR, FIXABLE AIR, OR AERIAL ACID.

FIXED AIR.

THE acid which is commonly known by the name of fixed air, abounds in great quantities in nature, and appears to be produced in a variety of circumſtances. It compoſes about one third of the weight of limeſtone, marble, calcareous ſpar, and other natural ſpecimens of calcareous earth, from which it may be extricated either by the ſimple application of heat, or by the ſuperior affinity of ſome other acid; moſt acids having a ſtronger action on bodies than this. This laſt proceſs has been before deſcribed. It does not require heat, becauſe fixed air is ſtrongly diſpoſed to aſſume the elaſtic ſtate. Water, under the common preſſure of the atmoſphere, and at a low temperature, abſorbs ſomewhat more than its bulk of fixed air, and then conſtitutes a weak acid. If the preſſure be greater, the abſorption is augmented. Heated water abſorbs leſs; and if water impregnated with this acid be expoſed on a briſk fire, the rapid eſcape of the aerial bubbles affords the appearance of the water being at the point of boiling, when the heat is not greater than the hand can bear. Congelation ſeparates it readily and completely from water; but no degree of cold or preſſure has yet exhibited this acid in a denſe or concentrated ſtate of fluidity.

Subſtances which contain fixed air.

Page 52—55.

Impregnation of water.

Fixed air is nearly twice as heavy as common air; and for that reaſon occupies the lower parts of ſuch mines or caverns as contain materials which afford it by decompoſition. The miners call it choke damp.

Groto del Cano.

The Grotto del Cano, in the kingdom of Naples, has been famous for ages on account of the effects of a ſtratum of fixed air which covers its bottom. It is a cave or hole in the ſide of a mountain near the lake Agnano, meaſuring not more than eighteen feet from its entrance to the inner extremity; where if a dog, or other animal that holds down its head, be thruſt, it is immediately killed by inhaling this noxious fluid.

Fixed air emitted from fermenting bodies.

Fixed air is emitted in large quantities by bodies in the ſtate of the vinous fermentation; and on account of its great weight it does not fly off, but remains in the upper ſpace of the veſſel, not occupied by the fermenting body. A variety of ſtriking experiments may be made in this ſtratum of elaſtic fluid. Lighted paper or a candle dipped into it, is immediately extinguiſhed; and the ſmoke remaining in the fixed air renders its ſurface viſible, which may be thrown into waves by agitation, like water. If a diſh of water be immerſed in this air, and briſkly agitated, it ſoon becomes impregnated, and obtains the lively taſte of Pyrmont water. In conſequence of the weight of the fixed air, it may be dipped out in a pitcher, or bottle; which, if well corked, may be uſed to convey it to great diſtances. The effects produced by pouring this inviſible fluid from one veſſel to another, have a very ſingular appearance: if a candle, or a ſmall animal, be placed in a deep veſſel, the former becomes extinct, and the latter expires, in a few ſeconds after the fixed air is poured upon them, though the eye is incapable of diſtinguiſhing any thing that is poured.

Experiments made in an atmoſphere of fixed air.

When

Converſion of vegetable matter into charcoal.

When vegetable ſubſtances are expoſed to a ſtrong heat in veſſels partly cloſed, the volatile principles fly off; but combuſtion does not take place for want of ir. The fixed reſidue is the inflammable ſubſtance alled charcoal. For general purpoſes, wood is conerted into charcoal by building it up in a pyranidical form, and covering the pile with clay or earth, eaving a few air-holes, which are cloſed when the naſs is perfectly lighted; and by that means the comuſtion is carried on in an imperfect manner. Comnon charcoal, when expoſed to heat in cloſed veſſels, ives out a ſmall quantity of inflammable air, which eems extraneous to it; and if it be burned, it leaves ſmall portion of earth, fixed alkali, and other ſalts. he greater part of charcoal therefore conſiſts of an nflammable ſubſtance; and it is found that, if this be urned in a cloſed veſſel over mercury, with vital air, he product is fixed air, and nothing elſe; as is proved y the reſidue after the fixed air has been abſorbed by uſtic fixed alkali: for there is either no aerial reſiue, or the reſidue conſiſts of vital air as pure as at rſt *.

Production of fixed air from charcoal.

Compoſition of fixed air.

Hence it follows, that fixed air conſiſts of the inmmable matter of charcoal united to vital air. The tiphlogiſtian philoſophers conſider this matter as a culiar combuſtible and acidifiable baſe, and thence fer the preſence of charcoal in all caſes where fixed r is extricated or produced: but, on the other hand, veral of the phlogiſtians think themſelves juſtifiable concluding that fixed air is produced by the union

Opinions.

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[*] Lavoiſier in Mem. Acad. Par. for 1781, p. 449.

of inflammable air with vital air, when either of them is in the naſcent ſtate, or ſtate of extrication.

The electric ſpark paſſed through fixed air.

When the electric ſpark* is paſſed through fixed air confined by mercury, the volume of air is augmented about one twenty-fourth part; and of this three fifths are abſorbed by a ſolution of cauſtic alkali, and the remainder is inflammable. An eminent philoſopher of the phlogiſtic opinion ſuppoſes this effect to ariſe from the decompoſition of the fixed air, whoſe vital air, combining more intimately with part of the inflammable air, forms water, the reſidue of this laſt air being diſengaged. But the chemiſt who made the experiment accounts for it as follows, without ſuppoſing the fixed air to be decompoſed :—The air of the atmoſphere, and other elaſtic fluids, are proved by experiment to be capable of retaining mercury in ſolution; ſo likewiſe in all probability does the fixed air: and they all retain much water. Whenever therefore the electric ſpark, by paſſing through this mixture of fixed air, mercury, and water, ignites a minute portion of it, the vital air of the water unites with and calcines the mercury; while the inflammable air of the water is ſet at liberty; and the fixed air, like other acids, unites to the mercurial calx, and falls down with it. He ſuppoſes, from analogy, that the water in the fixed air increaſes its volume by rarefying it; and that the ſubtraction of the water occaſions a contraction, while

Phlogiſtic explanation.

Antiphlogiſtic explanation.

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* This experiment, firſt performed by Prieſtley, I. 248, has ſince been repeated by Van Marum and others. The experiment of M. Monge, quoted by Kirwan in his Eſſay on Phlogiſton, p. 193, ſecond edition, is that ſpoken of in the text: and the opinions are thoſe of Meſſ. Kirwan and Monge.

the diſengagement of the inflammable air produces a ſomewhat greater augmentation of bulk. In this way (ſuppoſing the water and mercury to be preſent in ſufficient quantity) the whole of the fixed air may enter into a ſolid combination, and nothing remain but inflammable air. Additional experiments muſt however be made, before either opinion can be eſtabliſhed.

Combinations of fixed air; with clay:

Fixed air does not appear to be ſtrongly diſpoſed to unite with argillaceous earth. Moſt clays however afford a ſmall quantity of this fluid by heat; and the ſnowy white ſubſtance reſembling chalk, and known by the name of lac lunæ, is found to conſiſt of clay ſaturated with fixed air. A ſaline ſubſtance, conſiſting of two ſix-ſided pyramids joined at one common baſe, weighing five or ſix grains, and of a taſte ſomewhat reſembling alum, was produced by leaving an ounce phial of water, impregnated with fixed air and a redundancy of earth of alum, expoſed to ſpontaneous evaporation for ſome months.

—with calcareous earth:

Calcareous earth and fixed air have a ſtrong attraction for each other. Moſt of the ſpecimens of calcareous earth abound with this acid; and the immediate precipitation of lime from lime-water is the teſt of the preſence of this acid.

—with ponderous earth:

Ponderous earth combines very ſtrongly with fixed air. This compound has been found in England; and, like the foregoing, has already been treated of in the chapter on earths.

— with magneſia.

Magneſia unites readily to a large proportion of fixed air.

Page 106.

The uſual method of procuring magneſia is, by precipitation from a ſolution of Epſom ſalt, by adding an

Cryſtallized combination of magneſia with fixed air.

an alkali which combines with the acid. When a mild fixed alkali is uſed, it is neceſſary that the ſaline ſolutions ſhould be boiling hot, and the ebullition continued for a ſhort time, in order to diſſipate a portion of fixed air, which would hold part of the magneſia in ſolution. From this cauſe it is, that perfectly mild vegetable alkali affords no precipitate when added to a ſolution * of Epſom ſalt at the temperature of 60°. The mineral alkali, which contains leſs fixed air than the cryſtallized vegetable alkali, likewiſe affords but a ſmall quantity of precipitate, unleſs heat be applied. Mild volatile alkali alſo poſſeſſes the property of affording no precipitate when added to a ſolution of Epſom ſalt in the cold: with a greater heat magneſia is ſeparated; and at a boiling heat it is again taken up, moſt probably forming a triple ſalt compoſed of vitriolic acid united to volatile alkali and magneſia. The ſaline combination of magneſia and fixed air is ſeparated in cryſtals from all theſe cold ſolutions by ſtanding uncovered; during which time the fixed air, which held the magneſia in ſolution, is no doubt gradually diſſipated. The cryſtals afforded when vegetable alkali is uſed, are contaminated with vitriolated tartar, which ſeparates at the ſame time; thoſe obtained by mineral alkali are finer and purer: but the moſt beautiful and pureſt are obtained by leaving the ſolution to which volatile alkali has been added, expoſed for ſome days in an oblong veſſel,

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* One part Epſom ſalt, diſſolved in ſix parts water, was mixed with one part cryſtallized vegetable alkali, diſſolved in five parts water. Conſult Fourcroy in the Annales de Chimie, II. 282, from whom the whole of this article reſpecting aerated magneſia is taken.

This

Combinations of fixed air:

This cryſtallized aerated magneſia has uſually the orm of ſix-ſided priſms. It is almoſt taſteleſs; efflo-ces in the air; becomes pulverulent by heat, by he loſs of its fixed air and water; is ſoluble in about orty times its weight of water at the temperature of 5°. Half its weight conſiſts of fixed air, one fourth ater, and one fourth magneſia; whereas the common erated magneſia obtained by rapid precipitation con-ins forty parts magneſia, forty-eight fixed air, and elve water.

—with earths:

All the earthy combinations of fixed air are nearly ſoluble in water; they are all more ſoluble with an ceſs of that acid than in mere water; and they all ve out their fixed air by heat, except the native ſpe-men of aerated ponderous earth. This laſt contains water; and water ſeems to be eſſentially neceſſary enable bodies to aſſume the aerial form.

Fixed air has no action upon ſiliceous earth.

—and with alkalis:

The three alkalis form concrete cryſtallizable ſalts hen united with fixed air, which being in fact neu-l ſalts, are much leſs active than the cauſtic or pure alis themſelves. Theſe ſalts ſtill continue to be lled the mild alkalis; becauſe the fixed air, though forms a large proportion of their weight, is diſplaced moſt other acids, and therefore does not obviouſly m to impair their alkaline properties: beſides which, this volatile acid flies off in the elaſtic form, and loſt in common experiments (exhibiting no other lication of its preſence than the violent ebullition ich accompanies its eſcape), it was formerly over-ked, and even at the preſent time is not always ficiently attended to.

Alkaline air and fixed air unite, and form the concrete volatile alkali.

Combination of fixed air with combuſtible matter.

The combinations of fixed air with inflammable ſubſtances have not been accurately examined. Metallic calces uſually contain more or leſs of this acid. Plumbago, or black lead, is the moſt remarkable compound into which it enters. This affords much fixed air: but chemiſts are not agreed with reſpect to its combuſtible part; ſome conſidering it as the mere principle of inflammability, and others aſſerting it to be iron.

Advantages derived from a knowledge of this acid.

When we take a retroſpective view of the numerous difficulties in chemical ſcience reſpecting the mild and cauſtic ſtate of lime and alkalis, and their efferveſcence with acids in the one but not the other ſtate; the interrupted effects of affinities; the pernicious effects of caverns, or of places where charcoal i burned, or proceſſes of fermentation are carried on the nature of medicinal ſprings, and the componen parts of a large proportion of mineral as well as organized bodies, which embarraſſed the world befor the diſcovery of this acid; we have juſt reaſon t affirm that the name of Dr. Black of Edinburgh woul have been immortal, if this had been the only one o the many diſcoveries which he has added to the maſ of human knowledge.

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CHAP. V.

OF THE ACID OF BORAX.

BORAX.

Natural production of tincal or crude borax.

BORAX is a ſalt which comes to us from the Eaſt Indies, and whoſe origin has till lately been ery dubious. At preſent however it is very well ſcertained * that it is dug up in a cryſtallized ſtate om the bottom of certain ſalt lakes in a mountain- us, barren, volcanic diſtrict, about five-and-twenty ys journey to the eaſtward of Laſſa, the capital of e kingdom of Thibet. Tincal, or crude borax, the ſtate we receive it, is of a dull white or eeniſh colour, in irregular cryſtals, covered with rancid oily ſubſtance, ſaid to be added to prevent deliqueſcing, and intermixed with earthy impuri- es. It is not well known in what proportions the mponent parts exiſt in the borax when dug out of e earth; becauſe it is ſaid to be purified by ſubſe- ent ſolution in water and cryſtallization ſoon after comes from the mountains: and the borax of mmerce is chiefly refined in Holland by a proceſs hich is kept a ſecret; though there is little doubt t it conſiſts of ſolution, filtration, cryſtallization, d calcination, to free it from the impurities and eaſe; and afterwards a ſecond ſolution and cryſtal- zation, probably with an addition of mineral alkali, ſalt of ſoda. M. Chaptal, after trying various

Purification of borax.

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* Phil. Tranſ. Vol. LXXVII. No. 21. 29.

BORAX AND ITS ACID.

proceſſes in the large way, found the method of calcination to be attended with loſs; and approves of ſtrong and continued boiling with water, and cryſtallization, followed by a ſecond ſolution, ebullition, and cryſtallization, as the ſimpleſt method of purifying this ſalt *.

Analyſis of borax.

If borax be diſſolved to ſaturation in boiling water, and the vitriolic acid be added in ſuch a quantity as to be perceptibly in exceſs, a ſalt will be diſengaged, during the cooling, in white ſcales, which will ſwim at the ſurface of the fluid. Theſe being taken out, the remaining ſolution affords Glauber's ſalt by evaporation. This laſt ſalt, conſiſting of the vitriolic acid united to mineral alkali, affords a proof that the alkali was one of the component parts of the borax: and when, by adding the diſengaged ſcaly ſalt to mineral alkali in a due proportion, borax is reproduced, we have a complete proof that the ſcaly ſalt is the other component part. It was originally denominated ſedative ſalt, but is now known by the name of acid of borax.

The acid of borax may be obtained alſo by ſublimation; the alkaline baſe being ſeparated by the previous addition of ſome ſtronger acid.

Habitudes of borax:

Borax contains a larger proportion of alkali than is neceſſary to ſaturate the acid. Some of the alkali is ſaid to be added in the purification of the tincal. This purified ſalt requires about eighteen times its weight of water to diſſolve it, at the temperature of 60°. When heated, it ſwells up, loſes its water of cryſtallization, and runs into a kind of glaſs, which

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* Elements of Chemiſtry, Eng. Tranſlation, I. 277.

may

BORAX AND ITS ACID.

may be diſſolved in water, and cryſtallized, as before.

— and its acid.

The acid of borax requires about fifty times its weight of water to diſſolve it. In a moderate heat it melts with leſs intumeſcence than borax itſelf; and the glaſſy ſubſtance, thus formed, is again ſoluble in water, having only loſt its water of cryſtallization.

Borax is uſed as a flux in ſoldering, and its acid is a very uſeful flux for experiments with the blow-pipe.

Native acid of borax.

The acid of borax has been found uncombined in the waters of certain lakes in Tuſcany. There have been ſeveral accounts of the artificial production of borax ſaid to be practiſed in China, and verified by experiments made in France; but they all want farther confirmation.

Hard cryſtallized ſtone containing acid of borax.

It has lately been diſcovered that a cryſtallized ſtone, found in a cleft near the top of a ſtratified mountain compoſed of plaſter ſtone or gypſum, contains a large proportion of the acid of borax *. This mountain, which bears the name of Kalkberg, is ſituated near Luneberg in the duchy of Brunſwick; and the ſtone which has been called cubic quartz, but is known to the inhabitants of the vicinity by the name of wurfelſtein, is uſually of a white colour, often grey, and ſometimes of a violet tinge. Its figure, when perfect, appears at firſt ſight to be cubic; but, when attentively inſpected, is found to be compoſed of twenty-ſix faces. Moſt ſpecimens are opake;

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* See the Annales de Chimie, II. 101 and 137, for examinations of this mineral, by M. Weſtrumb and by M. Heyer. The former is referred to in the text.

Analyſis of the native combination of the acid of borax with lime and magneſia.

ſome are ſemi-tranſparent, and a few are perfectly tranſparent. The greater number of theſe cryſtals have the appearance of having been corroded. It is evidently of a laminated texture; though its fracture ſeems to exhibit a radiated appearance. Its ſpecific gravity is about 2.566, and its hardneſs is ſuch that it ſcratches glaſs, and gives fire plentifully with the ſteel.

This ſtone loſes its tranſparence by ignition, and becomes pulverable if quenched in water; though the hardneſs of its particles cauſes it to abrade the hardeſt mortars which can be uſed. An extreme degree of heat cauſes it to run into a yellow glaſs. Water does not diſſolve it, either cold or by ebullition. Alkalis act upon it in the dry way, but not readily; and in this operation a conſiderable loſs of weight is experienced. Acids, by long boiling upon the pulverized ſtone, diſſolve it for the moſt part. Five days boiling of marine acid upon one hundred grains of the ſtone diſſolved it at laſt.

The ſolution in marine acid firſt exhibited foliated cryſtals at its ſurface, which fell to the bottom; and as the evaporation proceeded, the whole maſs fixed into a yellowiſh white ſubſtance. This was ſoluble in water, and let fall a ſmall portion of ſiliceous earth. The ſolution, being examined by the methods of analyſis hereafter to be deſcribed, afforded a ſmall quantity of iron, with ſome lime; and, by the addition of vitriolic acid and ſublimation, the acid of borax was obtained. An additional quantity of this ſubſtance was afforded by waſhing the reſidue with the ſtrongeſt ardent ſpirit, and evaporating the ſolution till cryſtals were afforded. The component parts of the ſtone were thus found to

BORAX AND ITS ACID.

be—Acid of borax deprived of its water of cryſtallization by a red heat, 68 parts; magneſia, $13\frac{1}{2}$; lime, 11; clay, 1; calx of iron, 1; ſilex, 2; loſs in the operation, $3\frac{1}{2}$. By adding the mineral alkali to the acid thus obtained, a true borax was formed.

Combinations of the acid of borax with earths and alkalis.

The acid of borax combines in the humid way with the calcareous, ponderous, and magneſian earths, and alſo with the alkalis, forming compounds hitherto but little examined. It does not directly diſſolve the metals in the humid way; but notwithſtanding its weak affinity, compared with other acids, it is probable that the combinations might be effected by double affinity. It diſſolves ſiliceous earth in the dry way. Spirit of wine diſſolves it, and burns with a green flame when ſet on fire.

Suppoſed reduction of borax.

No attempts have been made to decompoſe this acid, or to exhibit it in the aerial form. Some German chemiſts have lately obtained a metallic ſubſtance by treating borax with charcoal in a ſtrong fire, in the way of reduction. But it is at preſent generally admitted that this metal was iron, from the crucible *.

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* Ruprecht in the Journal de Phyſique for 1790.

CHAP. VI.

OF THE ACID OF SPAR.

ACID OF SPAR.

Fluor or Derbyſhire ſpar.

THE fuſible ſpar, or fluor, which is commonly known in England by the name of Derbyſhire ſpar, contains a peculiar acid united to calcareous earth. The texture of this compound is either ſparry, or irregularly ſhattered or cracked. It is either tranſparent or opake; and the ſpecimens are of a cubic, rhomboidal, polygonal, or irregular figure. The coloured ſpars have the property of becoming phoſphoreſcent, or emitting light, when laid upon a hot iron, or otherwiſe heated; but they loſe this property by being made red hot. This ſpar is not ſufficiently hard to ſtrike fire with the ſteel. It is inſoluble in water, and does not efferveſce with acids.

Diſtillation of the acid.

If the pure fluor, or ſpar, be placed in a retort of lead, with a receiver of the ſame metal adapted, and half its weight of vitriolic acid be then poured upon it, the acid of ſpar will be diſengaged in the aerial form by the application of a gentle heat. This acid air readily combines with water; for which purpoſe it is neceſſary that the receiver ſhould previouſly be half filled with that fluid. When experiments are required to be made with the acid in the elaſtic ſtate, it muſt be received over mercury.

Diſtinctive character.

The diſtinguiſhing property which is moſt eminently, and almoſt excluſively, poſſeſſed by this acid, is that of diſſolving ſiliceous earth. The firſt experiments upon it were made with glaſs veſſels, and were attended with the ſingular phenomenon of an earthy matter being depoſited at the inſtant that the air came in contact with the water in the recipient. Upon examination it was found to be ſiliceous earth; and ſubſequent experiments proved that it was obtained by corroſion of the glaſs, and held in ſolution by the elaſtic fluid. This circumſtance ſhews the neceſſity of uſing metallic veſſels in the diſtillation.

Siliceous earth diſſolved.

The fluor acid has been ſucceſsfully uſed to make etchings on glaſs, in the ſame manner as the nitrous acid has long been applied to copper.

Etchings on glaſs.

With argillaceous earth it forms a neutral ſalt, of a gelatinous conſiſtence. With calcareous earth it produces the ſpar already treated of. With ponderous earth it forms a ſalt of difficult ſolution, which effloreſces in the air. It readily combines with magneſia, and forms a cryſtallizable ſalt: it takes this earth from every other known acid. With the vegetable alkali it affords a fuſible deliqueſcent ſalt; the ſolution of which, if ſufficiently evaporated, takes a gelatinous appearance. The mineral and volatile alkalis are ſaid to act nearly in the ſame manner.

Combinations with earths and alkalis:

This acid acts ſcarcely, if at all, upon gold, ſilver, lead, mercury, tin, antimony, biſmuth, or cobalt, though it diſſolves their calces. It acts directly upon iron and zinc, with the production of inflammable air; and it likewiſe diſſolves copper in the metallic ſtate, though leſs eaſily than when calcined.

—with metals.

CHAP. VII.

OF THE ACID OF AMBER.

AMBER.

Characters of amber:

AMBER is a hard brittle ſubſtance, ſometimes perfectly tranſparent, but moſtly ſemi-tranſparent, clouded, or opake. It is found of all colours, but chiefly yellow or orange. Some ſpecimens contain inſects or leaves. When broken, it preſents a poliſhed ſurface at the place of fracture. It is capable of a good poliſh, though always of a ſomewhat greaſy feel. By friction it becomes electric, and is the ſubſtance in which the operation of electricity was firſt taken notice of by the ancients. It emits an agreeable ſmell when rubbed or heated, and melts at a leſs temperature than is required to cauſe mercury to boil. With acceſs of air it is inflammable; but by diſtillation in cloſed veſſels it affords a ſmall portion of water, a concrete ſublimate which is the acid of amber, and an oil. A gentle heat is ſufficient to raiſe the acid; and care muſt be taken to regulate it ſo as not to drive up the oil, when the acid is required to be had in a ſtate of purity. The acid itſelf is ſoluble in twenty-four parts of cold water, and in a much leſs quantity when boiling hot. The ſublimed acid requires to be purified by repeated ſolutions and cryſtallizations.

— where found.

Amber is dug out of the earth in the Pruſſian dominions in greater plenty than elſewhere; but the beſt ſort is taken out of the ſea, or is caſt on ſhore by the waves. From its being found in the earth

AMBER.

in the neighbourhood of foſſil wood, as well as from other circumſtances, it is ſuppoſed to be of vegetable origin. Its analyſis evidently ſhews that it conſiſts of an oil rendered concrete by combination with an acid.

Combinations of the acid of amber.

The acid of amber combines with the earths, alkalis, and metallic calces. With clay it affords a ſalt in cryſtals; with lime and ponderous earth it produces ſalts of difficult ſolubility; and with magneſia, a compound reſembling gum. With the vegetable and volatile alkalis it forms cryſtallizable ſalts, which deliqueſce by expoſure to the air; but with the mineral alkali it forms a ſalt whoſe cryſtals are conſiſtent. With the calces of the metals it forms cryſtals which are for the moſt part permanent.

From its ſublimation in the form of flowers, it is evident that it cannot be exhibited in the aeriform ſtate but at a very elevated temperature. No inquiries have been made in the way of decompoſing it.

CHAP. VIII.

OF PHOSPHORUS AND ITS ACID.

PHOSPHORIC ACID.

Native phoſphorus.

THE phoſphoric acid, or its baſe, abounds in the animal and vegetable, as well as the mineral kingdoms. In this laſt it is found united to lead or iron, but perhaps moſt abundantly in combination with calcareous earth. It is aſſerted that there are whole mountains in Spain which conſiſt of a compound of lime and phoſphoric acid*. But the acid has been hitherto moſt commonly obtained from animal ſubſtances. Phoſphorus is a ſubſtance greatly reſembling ſulphur in colour and conſiſtence, in its uſual ſtate of purification; but it is leſs brittle, and much more inflammable. When very pure, it is of a clear tranſparent yellow colour. Like ſulphur, it burns with two kinds of flame. An heat of about 60° produces the weaker kind of flame, which ſcarcely affords any ſenſible degree of warmth. It has the appearance of white fumes in the day light, but is conſiderably luminous in the dark. If a veſſel containing a ſmall piece of phoſphorus be ſurrounded with water gradually heated, the fumes eſcape more and more rapidly; and when the water is heated to 160°, the phoſphorus takes fire, and burns with a ſtrongly vivid and deſtructive flame.

Characters of phoſphorus.

Page 140.

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* Annales de Chimie, I. 196.

This

PHOSPHORUS.

The diſcovery of phoſphorus; by Brandt, Kunckel,

This ſubſtance, remarkable for its extreme combuſtibility, and the exhibition of flame without heat, was firſt diſcovered about the year 1667, by a chemiſt whoſe name was Brandt. Another chemiſt, well known by his writings, whoſe name was Kunckel, diſcovered the ſecret of Brandt by a ſet of experiments expreſsly inſtituted for that purpoſe. It is to this philoſopher that the world has juſtly given the honour of the diſcovery. Our eminent Robert Boyle likewiſe made the diſcovery upon the ſame information probably as that of Kunckel; namely, that the phoſphorus was produced from urine. It is aſſerted that a certain dealer in ſecrets, one Krafft, communicated the proceſs to Boyle*; but it is not probable that a man of ſuch undoubted integrity as Boyle would have communicated the proceſs to the Royal Society as his own, if this had been the caſe. Neither indeed does the invention appear to be of that magnitude, as not to be eaſily hit upon by thoſe who were determined to ſpare no pains nor attention in the purſuit of diſcovery, as was the caſe with the chemiſts of that day, moſt of whom indulged extravagant hopes. The proceſs of Boyle conſiſted in nothing more than diſtilling urine till the laſt volatile product came over, which is the phoſphorus; and he uſed no other artifice to facilitate the operation, than that of firſt evaporating the fluid part of the urine until it became of the conſiſtence of ſyrup. He then mixed this liquid with thriee its weight of fine ſand, and expoſed the whole to diſtillation for

and Boyle.

Defence of Boyle as the inventor.

Proceſs of Boyle.

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[*] Stahlii CCC. Exper. ed. Berolini, Ann. 1731, p. 393.

twelve hours, the fire being made as intenſe as poſſible for the laſt ſix hours. Other proceſſes have ſince been invented to ſhorten this operation; but the late diſcovery of Scheele has ſuperſeded them all, on account of its greater expedition and cheapneſs.

Proceſs for obtaining phoſphorus from bones.

The fixed reſidue of bones, after burning, conſiſts of the acid of phoſphorus united to lime. If therefore this white friable ſubſtance be pounded, and paſſed through a ſieve, and a quantity of diluted vitriolic acid be added, leſs than is ſufficient to diſſolve the maſs, it will then conſiſt of a ſolution of ſelenite, with diſengaged phoſphoric acid. By evaporation of the clear liquid, the ſelenite ſeparates in cryſtals; and the decanted liquor, by farther evaporation to dryneſs, and the application of a conſiderable heat, affords the phoſphoric acid in the form of a white or tranſparent glaſs. If this acid be pounded, and mixed with one third of its weight of charcoal, in an earthen retort, it affords phoſphorus by diſtillation.

Phoſphoric glaſs.

The phoſphoric glaſs obtained in the firſt inſtance from bones, is not ſufficiently deprived of calcareous earth to be uſed in any other proceſs than that of making phoſphorus. For this purpoſe however it is not neceſſary to bring it to the conſiſtence of glaſs. The evaporation may be conveniently performed in a copper veſſel; and when the fluid has acquired the conſiſtence of ſyrup, it may be mixed with its own weight of charcoal in powder, and ſubmitted to diſtillation in a good earthen retort. Inſtead of applying a receiver, the neck of the retort may be immerſed in a baſon of water to a ſmall depth; and the phoſphorus, as it comes over, will fall in drops to the

bottom.

Proceſs for obtaining phoſphorus.

bottom. It is true that in the proceſs thus managed there will be apparently much phoſphorus burned by the admiſſion of the common air, which now and then paſſes into the neck of the retort, whenever the abſorption of the water cauſes its ſurface to fall below the aperture; but this quantity is really inconſiderable, and is compenſated by the ſimplicity and facility of the proceſs. The operator muſt be careful that the neck of the retort be not plunged to too great a depth; becauſe in this caſe the water would paſs into the body of the retort at the time of abſorption, before the ſurface of the water in the baſon had fallen ſufficiently to admit the air. The phoſphorus comes over as ſoon as the retort is red hot; and when the drops ceaſe, the whole apparatus muſt be ſuffered to cool. It has the form of reddiſh wax, or tallow; and may be preſſed together under the water while it is yet warm. If this be done with the naked hand, great care muſt be taken that no particle ſhall remain ſticking to the hands, or under the nails; as ſuch a particle, by taking fire when brought into the air, might produce very painful and diſagreeable conſequences. It may be moulded into ſticks, by putting the pieces into ſmall conical tubes of glaſs, cloſed at one end, and fixed upright in a piece of wood, the whole being immerſed under water: on heating the water, the phoſphorus will melt, and take the deſired form. The impurities that riſe to the upper ends of the tubes may be cut off when taken out, which muſt not be done till all is cool.

Page 57.

Purification of phoſphorus.

Phoſphorus may be had exceedingly pure by ſtraining it through a leather bag immerſed in hot water;

PHOSPHORIC ACID.

Purification of phoſphorus.

or, which is ſtill better, by diſtilling it a ſecond time with a very gentle heat. The blackiſh colour of phoſphorus is aſcribed to a portion of phoſphoric acid which is mixed with it. This diſappears almoſt entirely by boiling with a ſmall quantity of volatile alkali *; and if the phoſphorus be boiled two or three ſucceſſive times in ardent ſpirit, it becomes perfectly tranſparent, and of a beautiful copal colour, with very little loſs of weight.

Phoſphorus muſt be kept in a bottle of water, to prevent its gradual combuſtion.

Phoſphoric acid, obtained by ſlow combuſtion.

If a number of ſticks of phoſphorus be placed upright in a glaſs funnel, a piece of glaſs tube being previouſly put into the neck of the funnel to prevent their falling through; and if this funnel be then inſerted in the neck of a bottle containing diſtilled water, the phoſphorus will be decompoſed by the ſlow combuſtion, provided it be expoſed to a temperature higher than that of 60°; and the phoſphoric acid will gradually paſs through the funnel into the water. The acid thus obtained contains a portion of phoſphorus; but, by expoſure to the air, this alſo becomes converted into acid: or the ſuperfluous portion of phoſphorus may be burned by cauſing the acid to boil.

Concrete phoſphoric acid.

Page 202.

If the water be evaporated from the phoſphoric acid, it may be converted by heat into a ſolid tranſparent ſubſtance, which differs from that obtained immediately from bones by the vitriolic acid, in attracting the humidity of the air, and its ſolubility in water. It is ſaid however that a ſtronger heat will render

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* Annales de Chimie, I. 234.

it

PHOSPHORIC ACID.

it permanent, and deprive it of acidity; which change moſt probably ariſes from its combining with the earth of the crucible.

Phoſphoric acid; obtained by the action of nitrous acid:

Phoſphorus may likewiſe be converted into phoſphoric acid by treating it with nitrous acid. In this operation a tubulated retort, with a ground ſtopper, muſt be half filled with concentrated nitrous acid, and a gentle heat applied. Small pieces of phoſphorus being then introduced through the tube, will be diſſolved with an effervefcence, which is produced by the eſcape of a large quantity of nitrous air. This addition of phoſphorus muſt be continued until the laſt piece remains undiſſolved. The fire being then raiſed to drive over the laſt portions of nitrous acid, the phoſphoric acid will be found in the retort; partly in the concrete, and partly in the liquid form.

— by vitriolic acid:

Vitriolic acid produces nearly the ſame effect as the nitrous; but, being leſs volatile, it is leſs adapted to the purpoſe.

— by ſtrong combuſtion:

The ſtrong combuſtion of phoſphorus effects a decompoſition nearly complete, and leaves the acid in a dry ſtate.

— by a ſtream of vital air.

Phoſphoric acid is likewiſe produced by paſſing a ſtream of vital air through phoſphorus liquefied in hot water.

Phoſphoric hepar; and air.

Phoſphorus combines with the cauſtic fixed alkalis in a boiling heat, and forms an hepar; during which a peculiar elaſtic fluid is given out, which poſſeſſes the remarkable property of taking fire as ſoon as it communicates with the air of the atmoſphere. This air has evidently the ſame relation to phoſphorus as the common hepatic air has to ſulphur; and, like that,

Page 138.

PHOSPHORIC ACID.

that, it probably conſiſts of a ſolution of the phoſphorus in inflammable air.

Combination of phoſphorus with ſulphur:

Sulphur and phoſphorus unite by fuſion, and form a ſolid compound of a fetid ſmell, which burns with a yellow flame, and ſwells in water; at the ſame time communicating acidity to that fluid, and emitting a ſmell of hepatic air. All kinds of oils diſſolve phoſphorus, and are rendered luminous by it: ſeveral eſſential oils form a ſolution which takes fire by expoſure to the air, probably in conſequence of the emiſſion of phoſphoric air. The butter of wax, which conſiſts of wax deprived of part of its acid by diſtillation, is ſaid to be the propereſt material for producing this effect. Very ſtrong ardent ſpirit diſſolves a ſmall portion of phoſphorus, which gives a perceptible light upon the addition of water. Metals do nót readily combine with this ſubſtance when ſimply heated with it: but when the phoſphoric acid, together with charcoal, is expoſed to a ſtrong heat, a conſiderable number of the metals may be made to unite with it*, probably in conſequence of their being previouſly calcined by the acid.

— with oils:

—ardent ſpirits:

— metals.

Metals revived by phoſphorus.

When a ſtick of phoſphorus is plunged in the ſolutions of gold, ſilver, copper, and other metals, the phoſphorus becomes gradually covered with a brilliant metallic ſheath, the phoſphorus becoming acidified as the metal is revived.

Uſes of phoſphorus.

Phoſphorus has not yet been applied to any uſe, excepting that a few trials have been made of its efficacy in medicine. The luminous appearance of writing made of a ſtick of phoſphorus upon paper, or any other ſubſtance which can abrade it, is ſufficiently known. There is ſome danger of its catching fire if the friction be ſwift or violent; and for that reaſon the ſtick of phoſphorus ought to be held in a metallic caſe, and a cup of water ſhould be at hand to plunge it in. It is alſo uſed when diſſolved in eſſential oils, or butter of wax, to make tapers or matches, intended to ſupply the place of flint and ſteel n producing light; but it is not probable that theſe will ever be afforded ſufficiently cheap to anſwer the purpoſe of a ſubſtitute to that operation.

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* Journal de Phyſique, for March 1789.

Phoſphoric matches.

The acid of phoſphorus exiſts, as has been already obſerved, in two ſtates ſimilar to thoſe of the volatile and fixed vitriolic acids: and the difference between heſe ſtates ariſes likewiſe from a ſimilar cauſe; namey, that a part of the phoſphorus is not converted nto acid, but is held in ſolution by that part which s acidified. Neither of the kinds of phoſphoric acid iſes totally by heat like the volatile vitriolic acid: but that which contains phoſphorus emits white fumes, which ſeem to conſiſt of part of the acid combined with the redundant phoſphorus; and the reſidue melts nto the vitreous form. This difference between the itriolic and phoſphoric acids depends no doubt upon he greater degree of fixity of the latter.

Two ſtates of phoſphoric acid.

Page 140. 143.

The phoſphoric acid does not appear to act upon liceous earth, though it corrodes glaſs when hot. It nites with clay in the dry way. With calcareous arth it forms a combination ſcarcely ſoluble in water, nleſs there be an exceſs of acid: it has been already noticed that the earthy reſidue of bones conſiſts of

Combinations of phoſphoric acid.

PHOSPHORIC ACID.

this ſubſtance. With ponderous earth it forms a ſalt whoſe properties are little known; and with magneſia it forms a cryſtallizable compound of difficult ſolubility.

Combinations of phoſphoric acid with alkalis.

This acid, when in combination with the vegetable alkali, forms a very ſoluble ſalt, which is ſuſpended in conſiderably greater quantity in hot than in cold water. It ſeparates from the liquid in cryſtals, either by cooling or evaporation. The combination of phoſphoric acid with mineral alkali conſtitutes a ſalt of an agreeable taſte, reſembling that of common ſalt. It is not eaſily cryſtallized, by reaſon of its diſpoſition to form an adheſive matter by evaporation, which reſembles gum. A ſmall exceſs of alkali renders it more diſpoſed to cryſtallize, and cauſes it to effloreſce by expoſure to the air. This ſalt has been lately introduced into medicine. The combination of volatile alkali with phoſphoric acid is likewiſe more ſoluble in hot than in cold water, and affords cryſtals by cooling. An exceſs of alkali renders the cryſtallization more eaſy. It is greatly diſpoſed to fly off by a gentle heat.

Phoſphoric ſalts from urine.

The phoſphoric ſalts were firſt obtained from urine. This animal fluid conſiſts of a large quantity of water; the acids of phoſphorus and of the calculus of the bladder, both in a diſengaged ſtate; ſome common ſalt, with the ſaline combinations of the phoſphoric acid with lime, mineral alkali, and volatile alkali; and two kinds of extractive matter, one of which is ſoluble in ardent ſpirit, and the other in water. When urine is expoſed to evaporation by heat, it aſſumes a darker colour; and a pulverulent matter falls down, which conſiſts of the calcareous phoſphoric ſalt, and the acid of the human calculus. If the urine be filtered as ſoon as it has acquired a viſcid conſiſtence, it affords ſaline cryſtals by cooling. Theſe conſiſt of the common ſalt, and alſo of a triple combination of phoſphoric acid with the mineral and vegetable alkalis, which is generally known by the name of microcoſmic ſalt. Repeated evaporations and coolings are required to deprive urine of the moſt part of its ſalts. Subſequent ſolution in water, heated and cooled in cloſed veſſels, purifies the phoſphoric cryſtals, and ſeparates the ſalt with the baſe of volatile alkali from that which contains mineral alkali. As the former of theſe ſalts only is decompoſed by heating with charcoal, it is from this alone that the phoſphorus of urine is obtained. The combination of mineral alkali with phoſphoric acid was for ſome time ſuppoſed to be a peculiar acid, and was called the perlate acid.

Salts from urine.

Microcoſmic ſalt.

Perlate acid.

The microcoſmic ſalt has been applied to great uſe by the celebrated Bergman, as a flux in blow-pipe experiments.

Phoſphoric acid unites with ſeveral of the metallic calces. It acts upon oils, to ſome of which it communicates a peculiar flavour, and it thickens others. It has not been well decided whether it can be exhibited in the claſtic ſtate at the temperature of the atmoſphere.

Combinations of phoſphoric acid with metals and oils.

The ſaline compounds formed by the phoſphoric acid, when not totally acidified, appear to differ from thoſe of the complete acid; but few experiments have been made with theſe.

The theory of the converſion of phoſphorus into

Theory.

PHOSPHORIC ACID.
Theory.

an acid, and the reduction into its original ſtate by treatment with charcoal, is perfectly ſimilar to that of ſulphur and vitriolic acid. When phoſphorus is burned, there is an abſorption of vital air, at the ſame time that phlogiſton, or the principle of inflammability, is ſuppoſed to be extricated. In this manner the phoſphorus is converted into an acid, which, when water is not preſent, has the appearance of white flakes; and in every ſtate weighs conſiderably more than the phoſphorus itſelf. On the other hand, when phoſphoric acid is heated with charcoal, the vital air is abſorbed by the latter; at the ſame time that the phoſphoric baſis is ſuppoſed to receive phlogiſton from the charcoal, and by that means recovers its original ſtate. According to the new theory, the phoſphorus is conſidered as a ſimple ſubſtance, relatively to the preſent ſtate of our knowledge; its converſion into an acid being ſuppoſed to conſiſt merely in the abſorption of vital air, and its revivification in the diſengagement of that ſubſtance.

CHAP. IX.

OF THE METALLIC ACIDS; OF ARSENIC, OF MOLYBDENA, AND OF TUNGSTEN, OR WOLFRAM.

ACIDITY.

Retroſpect of the facts and doctrines contained in the preſent ſection.

IN the preceding chapters we have exhibited a number of inſtances in which the proceſs of combuſtion has converted inflammable ſubſtances into acids: whence it may be inferred, as a general rule, that acidity is the ſtate of a combuſtible body, which is burned, either completely or nearly ſo; whether ſuch combuſtion be made to conſiſt in the diſengagement of phlogiſton and abſorption of pure air, or whether it be ſtated ſimply as the latter effect. We have ſeen that ſulphur, which is highly inflammable, becomes converted into vitriolic acid air, which is not at all inflammable; and that, when completely burned, it becomes vitriolic acid, in which the peculiar properties of that claſs of bodies are moſt eminently ſeen. Phlogiſticated air, which, by reaſon of its ſlight tendency to unite with vital air, appears to require either a long expoſure to that ſubſtance, or the ſucceſſive ignition of its parts by electricity, is found to form nitrous air when the combuſtion is incomplete—a ſubſtance which has no acid properties; but which becomes nitrous acid of various degrees of acidity, according to the doſe of vital air it may be combined with, and perhaps the extrication of phlogiſton. The metals have been ſhewn to be combuſtible, as well by

the

METALLIC ACIDS.

Acidification of metals.

the action of acids, as by heating them with acceſs of pure air. When they are thus calcined they become ſoluble in acids. Some of the metallic bodies have been diſcovered to be ſuſceptible of a farther continuation of the proceſs by which they are calcined; and this continuation is found to change them into acids ſoluble in water, and diſpoſed to combine with and neutralize alkaline ſubſtances. Hence there ſeem to be certain periods of combuſtion at which the ſame ſimple baſis becomes ſucceſſively converted into a calx, or ſubſtance capable of neutralizing acids; and afterwards into one which combines with and neutralizes alkalis. If we might generalize this, it would be fair to conclude that all metals are, in their own nature, capable of being converted into acids; that all acids are reducible to inflammable ſubſtances, though art has not yet deviſed the means of doing it in every inſtance; and it might be conjectured that the fixed alkalis themſelves may conſiſt of combinations of inflammable ſubſtances with pure air, to which they may adhere with too ſtrong an affinity to be ſeparated by means of any medium we are acquainted with.

General inferences; by conjecture.

Metals acidified.

The metallic ſubſtances which have been acidified are, arſenic, molybdena, and wolfram.

Arſenic.

Arſenic is a ſubſtance which combines with and mineralizes many of the metals, and is ſublimed from them in the form of a white calx. It is not clearly aſcertained, in a number of inſtances, whether the metals be combined with this calx, or with the metal, or with the acid it is capable of being converted into. If this white calx be diſſolved in three times its weight of boiling muriatic acid in a tubulated retort, and twice its weight of nitrous acid be then added, and the evaporation ſtill continued, the former acid will fly off in the elaſtic ſtate; while the nitrous acid will be decompoſed, and will convert the arſenic into a concrete acid. The purity of this may be aſcertained by igniting it; for this degree of heat will drive off any portion of the other acids that may remain.

Proceſs for obtaining the arſenical acid.

Characters of arſenical acid.

The arſenical acid is much more fixed in the fire than the calx itſelf; it may even be fuſed into a tranſparent glaſs. It is ſlightly deliqueſcent, and requires twice its weight of water to diſſolve it. This acid forms a ſaline combination with argillaceous earth, which coagulates as ſoon as it arrives at the point of ſaturation. With lime it forms a cryſtallizable ſalt. With ponderous earth it forms a ſalt of difficult ſolubility. With magneſia it produces a coagulum, or gelatinous ſubſtance. It does not act upon ſiliceous earth, unleſs perhaps in the dry way.

Combinations with earths:

—with alkalis.

The combination of this acid with vegetable alkali forms a deliqueſcent ſalt, which does not cryſtallize; but if there be a ſmall exceſs of the acid, the ſolution will afford fine cryſtals, which are the neutral arſenical ſalt of Macquer. The mineral alkali, ſaturated with arſenical acid, affords a cryſtallizable ſalt nearly reſembling the foregoing. It unites likewiſe with the volatile alkali, and forms a ſalt in cryſtals. When this is expoſed to diſtillation, part of the alkali is decompoſed; phlogiſticated air is given out; and the acid, being reduced to the calciform ſtate, ſublimes.

Page 124.

Mere heat in an open veſſel gradually reduces the acid of arſenic to the ſtate of calx, which ſublimes.

Reduction of arſenical acid.

limes. When the fluid acid is digeſted with charcoal powder, no change takes place until the moiſture is evaporated; and when the heat is raiſed to ignition, a ſudden combuſtion takes place, all the acid is reduced and ſublimed into the neck of the retort, the greater part being in the form of the metallic regulus, and the reſt calx. Continued digeſtion with oils revives this acid. It unites with ſulphur by fuſion, the whole maſs riſing almoſt inſtantly in the form of a red ſublimate, at the ſame time that volatile ſulphureous acid paſſes into the receiver.

Combination with ſulphur.

Theory.

The theory of theſe facts will not be difficult to the reader who has attentively conſidered the preceding chapters. The white calx of arſenic was diſſolved in marine acid; becauſe it is required to be had in a ſtate of extreme diviſion, and becauſe the nitrous acid can only diſſolve it very ſparingly. The nitrous acid is added; becauſe it readily gives out vital air (and perhaps abſorbs phlogiſton), while it becomes converted into nitrous air, which flies off. The calx of arſenic thus becomes completely acidified. This acid, at a ſtrong temperature, decompoſes volatile alkali, which is a compound of phlogiſticated and inflammable air. This laſt principle either affords phlogiſton to the acid, and reduces it to the ſtate of a calx; or, according to the new theory, performs the ſame thing by uniting with the vital air, and forming water. And a ſimilar explanation will ſerve for the effects of charcoal, or oils, which either afford phlogiſton, or abſorb the vital air. With reſpect to the effects of ſulphur, part of it is acidified by combuſtion, or combination with the vital air of the acid, and comes over in the form of vitriolic acid air; while the reſt combines with the arſenic, which is reduced, but in what degree does not clearly appear.

Characters of molybdena.

Proceſs for obtaining the acid of molybdena.

Molybdena is a ſubſtance which greatly reſembles plumbago, or black lead; but its texture is ſcaly, and it is not eaſily pulveriſed, on account of a degree of flexibility which its laminæ poſſeſs. If it be triturated in a mortar with vitriolated tartar, this ſaline ſubſtance will, by the hardneſs and angular figure of its particles, render it more eaſily pulverable; and when this purpoſe is accompliſhed, the ſalt may be waſhed away by ſeveral affuſions of water. If the powder be then placed in a retort, with five or ſix times its weight of diluted nitrous acid, and diſtillation be carried on to dryneſs, it is found that volatile vitriolic acid and nitrous air are extricated, and the colour of the reſidue becomes lighter. More acid muſt then be added, and the diſtillation again repeated till the fourth or fifth time. A ſtrong heat is required to drive off the laſt portions of vitriolic acid formed by the ſulphur. When no more red vapours appear, the reſidue will be white and pulverulent, reſembling chalk. This is the acid of molybdena. It requires near five hundred times its weight of boiling water to diſſolve it, and exhibits weak acid properties.

Combinations.

This acid combines with lime, magneſia, and calcareous earth, with which it forms ſalts of very difficult ſolution. When added to a ſolution of ponderous earth in the nitrous or marine acids, it forms a compound which is ſparingly ſoluble in cold water; and, on that account, falls to the bottom. The combi-

METALLIC ACIDS.

nation of this acid with vegetable alkali is more ſoluble in water than the acid itſelf, and affords cryſtals by evaporation. It unites likewiſe with the volatile alkali. Several of the metals, when diſſolved, are likewiſe ſeized by this acid, and precipitated from their ſolutions.

Regenerated molybdena.

When the acid of molybdena is heated with ſulphur in a retort, placed in ſuch a manner as that the ſublimed ſulphur may melt and run back again, a combination between theſe two ſubſtances is at length produced; and the ſuperfluous ſulphur flies off, being partly converted into volatile vitriolic acid. The reſidue is found to be in every reſpect the ſame as the native molybdena. The analyſis of molybdena by the nitrous acid ſhewed that it conſiſts of ſulphur united to a peculiar acid, or acid baſis; and this ſynthetical production of molybdena proves the ſame thing.

Acid of tungſten, or wolfram.

The acid of tungſten, or wolfram, is a peculiar metallic ſubſtance obtained from theſe minerals. The tungſten is a ponderous ore, of a grey colour, and lamellar texture. It conſiſts of the metallic calx, or acid, united to about its own weight of calcareous earth. Wolfram is a mineral of ſtill greater ſpecific gravity, which is formed in the tin mines of Cornwall, and elſewhere. It is of a browniſh black colour, of a radiated or foliated texture, internally ſhining almoſt with the luſtre of a metal. It is of a moderate hardneſs, though ſometimes ſo friable as to be pulverable between the fingers. It contains about two-thirds of the peculiar calx or acid; and the

Proceſs for obtaining the acid of tungſten, or wolfram.

reſt conſiſts chiefly of the calces of manganeſe and iron. If either of theſe minerals be pulverized and digeſted in the vitriolic, nitrous, or marine acids (but the latter is the moſt effectual), the calcareous earth of the tungſten, or the manganeſe and iron of the wolfram, which lie on the external ſurfaces of the particles, will be diſſolved; and the wolfram calx, being laid bare, will exhibit a yellow colour. The reſiduum, after edulcoration, or waſhing with water, being digeſted with volatile alkali, the wolfram calx, or acid, will be taken up, or extracted from the ſurface, in the ſame manner; the yellow colour vaniſhng at the ſame time. This reſidue, after edulcoraion, will again preſent a ſurface to be acted upon by he marine acid, which will ſeize another ſtratum of particles, that in the former digeſtion were defended by the wolfram calx, which was afterwards taken up by the volatile alkali. In this manner, by the alternate pplication of volatile alkali and marine acid, the mineral will at length be almoſt entirely diſſolved. The portions of acid are found to contain either the alces of manganeſe and iron, or elſe calcareous earth, ccording to the mineral made uſe of; and the alkane ſolvent contains the acid of wolfram. The addiion of nitrous acid to this laſt fluid precipitates a ſalt which has acid properties, and is ſparingly ſoluble in water. The firſt diſcoverer* called it the acid of ungſten, though in fact it contains both volatile alali and nitrous acid. It may however be deprived f theſe laſt by calcination, and is then of a brimſtone ellow colour.

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* Scheele.

The yellow colour produced by applying marine or nitrous acid in a digeſting heat, affords an eaſy method of diſtinguiſhing ſuch minerals as contain wolfram.

Proceſs for obtaining the acid of tungſten, or wolfram.

In the dry way, if the vegetable alkali be fuſed with either of theſe minerals, it takes up the calx or acid. This being diſſolved in water, filtered, and evaporated to dryneſs, muſt be boiled in nitrous acid on a ſand bath. The acid takes up the alkali, and may be decanted off. A repetition of this boiling for two or three times with freſh acid, will effectually carry off the whole of the alkali; and the adhering acid may be driven off by calcination in a cupelling furnace. The powder is then yellow, and does not differ from that obtained by the diſtillation of volatile alkali in the moiſt way.

Characters of the acid.

This matter is not ſoluble in water; but when triturated in that fluid it forms an emulſion, which paſſes through the filtre, and does not completely ſubſide in the courſe of three months. This does not form an emulſion with acids. Pure vegetable alkali diſſolves it, as has been already obſerved; but the produce has always an exceſs of alkali. If more nitrous acid be added than is ſufficient to ſaturate the alkali, a precipitate falls down, which conſiſts of acid, alkali, and wolfram calx. The addition of lime to this, or to the precipitate from volatile alkali, produces a regenerated tungſten, or combination of lime with the wolfram calx or acid; and the alkali, together with the nitrous acid, are found in the ſupernatant fluid.

It

METALLIC ACIDS.

It is ſeen * therefore that this yellow matter is either n acid, or in a ſtate nearly approaching to acidity: or it is not combinable with acids, and unites readily o alkalis and calcareous earth.

Arſenic, molybdena, and wolfram, are reducible to he metallic ſtate, and will again come under our nſpection when we treat of that claſs of bodies.

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[*] The beſt account of this ſubſtance is to be found in "De Luyart's Chemical Analyſis of Wolfram," of which a tranſlation was printed in London, 1785, with Scheele and Bergman's papers prefixed.

BOOK II.

PARTICULAR CHEMISTRY.

SECTION III.

OF METALLIC BODIES.

CHAP. I.

CONCERNING GOLD.

GOLD.

Characters of gold.

GOLD is a yellow metal, of much greater ſpecific gravity than any other body in nature, except platina. It is ſoft, very tough, ductile, and malleable; unalterable and fixed, whether expoſed to the atmoſphere, or to the ſtrongeſt heat of furnaces. The moſt powerful burning mirrors are ſaid to have volatilized it; and it has been driven up in fumes, in the metallic ſtate, by flame urged upon it by a ſtream of dephlogiſticated air. The electric ſhock converts it into a purple calx, as may be ſeen by tranſmitting that

Obvious properties.

that commotion through gold leaf between two plates of glaſs; or by cauſing the exploſive ſpark of three or more ſquare feet of coated glaſs to fall upon a gilded ſurface. A ſtrong heat is required to melt it, which does not happen till after ignition. Its colour when melted is of a blueiſh green; and the ſame colour is exhibited by light tranſmitted through gold leaf.

Extreme ductility and tenacity.

The limits of the ductility and malleability of gold are not known; and its tenacity exceeds that of any other metal. A gold wire, of one tenth of an inch diameter, requires 500lb. weight to break it.

Manufacture of gold leaf:

— its thickneſs.

Gilt wire.

The method of extending gold, uſed by the gold-beaters, conſiſts in hammering a number of thin rolled plates between ſkins or animal membranes. By the weight and meaſure of the beſt wrought gold leaf, it is found that one grain is made to cover $56\frac{3}{4}$ ſquare inches; and from the ſpecific gravity of the metal, together with this admeaſurement, it follows, that the leaf itſelf is $\frac{1}{282000}$ part of an inch thick. This however is not the limit of the malleability of gold; for the gold-beaters find it neceſſary to add three grains of copper in the ounce to harden the gold, which otherwiſe would paſs round the irregularities of the neweſt ſkins, and not over them; and in uſing the old ſkins, which are not ſo perfect and ſmooth, they proceed ſo far as to add twelve grains. The wire which is uſed by the lace-makers is drawn from an ingot of ſilver, previouſly gilded. In this way, from the known diameter of the wire, or breadth when flattened; and its length, together with the quantity of gold uſed; it is found by computation that the covering of gold is only $\frac{1}{12}$ part of the thickneſs of gold leaf; though it ſtill is ſo perfect as to exhibit no cracks when viewed by a microſcope.

Solvents.

No acid acts readily upon gold but aqua regia and the dephlogiſticated marine acid. The vitriolic acid diſtilled from manganeſe has ſome action upon it; as have likewiſe the pale nitrous acid, and the phoſphoric acid when boiling.

Aqua regia.

The ſmall degree of concentration which the dephlogiſticated marine acid is ſuſceptible of, and the imperfect action of the latter acids, render aqua regia the moſt convenient ſolvent for this metal.

Solution of gold.

When gold is immerſed in aqua regia, an efferveſcence takes place with the eſcape of air, which has not been examined; the ſolution tinges animal matters of a deep purple, and corrodes them. By careful evaporation, fine cryſtals of a topaz colour are obtained. The gold is precipitated from its ſolvent by a great number of ſubſtances. Lime and magneſia precipitate it in the form of a yellowiſh powder. Alkalis exhibit the ſame appearance; but an exceſs of alkali rediſſolves the precipitate. The precipitate of gold obtained from aqua regia by the addition of a fixed alkali, appears to be a true calx, and is ſoluble in the vitriolic, nitrous, and marine acids; from which however it ſeparates by ſtanding, or by evaporation of the acids. The nut gall precipitates gold of a reddiſh colour, very ſoluble in the nitrous acid, to which it communicates a fine blue colour.

Precipitates: — by earths and alkalis:

— volatile alkali.

The volatile alkali precipitates the ſolution of gold much more readily than fixed alkalis. This precipitate, which is of a brown, yellow, or orange colour,

poſſeſſes

Production of fulminating gold.

poſſeſſes the property of detonating with a very conſiderable noiſe when gently heated. It is known by the name of fulminating gold. The preſence of volatile alkali is neceſſary to give the fulminating property to the precipitate of gold; and it will be produced by precipitating it by fixed alkali from an aqua regia previouſly made by adding ſal ammoniac to nitrous acid, or by precipitating the gold from pure aqua regia by means of ſal ammoniac inſtead of the volatile alkali alone. The fulminating gold weighs one fourth more than the gold made uſe of. A conſiderable degree of precaution is neceſſary in preparing this ſubſtance. It ought only to be dried in the open air, at a diſtance from a fire, becauſe a very gentle heat may cauſe it to explode. Several fatal accidents have ariſen from its exploſion, in conſequence of the friction of ground ſtoppers in bottles containing this ſubſtance, of which a ſmall portion remained in the neck.

— Analyſis.

Page 50.

Fulminating gold, when expoſed by Berthollet to a very gentle heat in a copper tube, with the pneumatical apparatus of mercury, was deprived of its fulminating quality, and converted into a calx, at the ſame time that alkaline air was diſengaged. From this dangerous experiment it is aſcertained that fulminating gold conſiſts of calx of gold, combined with the volatile alkali. The ſame eminent philoſopher cauſed fulminating gold to explode in copper veſſels. Phlogiſticated air was diſengaged, a few drops of water appeared, and the gold was reduced to the metallic form. From this experiment he infers that the volatile alkali was decompoſed; that the phlogiſticated air, ſuddenly aſſuming the elaſtic ſtate, cauſed the exploſion; while the vital air of the calx united with the inflammable air of the alkali, and formed the water.

Theory.

This ſatisfactory theory was ſtill further confirmed by that decompoſition of fulminating gold, which takes place in conſequence of the action of the concentrated vitriolic acid, of melted ſulphur, fat oils, and ether; all which deprived it of its fulminating quality by combining with its volatile alkali.

Precipitation of gold by liver of ſulphur:

Liver of ſulphur precipitates gold from its ſolvent; the alkali uniting with the acid, and the gold falling down, combined with the ſulphur; of which however it may be deprived by moderate heat.

— by metallic ſubſtances.

Moſt metallic ſubſtances precipitate gold from aqua regia; lead, iron, and ſilver precipitate it of a deep and dull purple colour; copper and iron throw it down in its metallic ſtate; biſmuth, zinc, and mercury, likewiſe precipitate it. A plate of tin immerſed in a ſolution of gold affords a purple powder, called "the purple powder of Caſſius," which is uſed to paint in enamel. There are various methods of managing this proceſs. That deſcribed by Macquer conſiſts in diſſolving tin by very ſmall portions at a time without heat, in an aqua regia compoſed of two parts of nitrous, and one of marine acid, previouſly weakened with water equal in weight to both the acids. The firſt ſmall portion of tin muſt be ſuffered to be entirely diſſolved before a ſecond is added. This addition muſt be continued till the acid has acquired a yellow colour, and ſcarcely acts at all upon the tin laſt added.

Proceſs for making the purple powder of Caſſius.

Proceſs for making the purple powder of Caſſius.

On the other hand, the pureſt gold muſt be diſſolved in an aqua regia, compoſed of three parts of nitrous, and one of marine acid. This ſolution may be made as expeditiouſly as the operator chooſes by the aſſiſtance of the heat of a ſand bath.

The ſolution of tin muſt then be largely diluted; as, for example, with one hundred parts of diſtilled water; and a ſmall quantity of this may then be aſſayed by ſeparating it into two parts, and diluting one of the parts ſtill farther. Upon trial of both, by letting fall a drop of the ſolution of gold into each, it will be ſeen which affords the moſt beautiful purple precipitate. The whole of the ſolution of tin muſt accordingly be altered, if neceſſary, by adding more water. Pour into this ſolution, in a large glaſs or earthen veſſel, nearly half as much of the ſolution of gold as it contains of ſolution of tin, ſtirring the mixture with a glaſs ſtick. In a ſhort time the liquor will become of a beautiful red colour, which will gradually diſappear by the ſubſidence of the precipitate. By adding a ſmall quantity of ſolution of tin, it will be ſeen whether the whole of the gold is precipitated. The clear liquor muſt then be decanted, and the precipitate waſhed. It conſiſts of the calces of gold and tin in combination, and is the only known ſubſtance which has the property of communicating a purple colour to glaſs.

Obſervations.

The difficulties attending the preparation of this article appear to depend on the ſtate of the tin. If the ſolution of this metal be made with heat and rapidity, it becomes too much calcined to adhere to the acid, or to precipitate the gold; and the combination of the two metals which falls down, varies in colour accordingly as this term is approached. Theſe are the chief circumſtances; but there is no doubt that a complete examination of the proceſs would indicate others worthy of notice.

Solutions of gold in ether, &c.

Ether, naptha, and eſſential oils, take gold from its ſolvent, and form liquors which have been called potable gold. The gold which is precipitated by evaporation of theſe fluids, or by the addition of martial vitriol to the ſolution of gold, is of the utmoſt purity.

Gold reſiſts nitre:

— but is rendered pale by borax:

In the dry way, gold reſiſts the action of neutral ſalts, more eſpecially nitre, which deflagrates with the imperfect metals. Nitre however does not afford an expeditious way of purifying gold, becauſe this metal in ſome meaſure protects and covers the alloys from its action. It is remarked that borax, uſed as a flux with gold, renders it paler; and that this alteration of colour diſappears by the addition of nitre, or common ſalt. As the acid of borax forms a compound with gold, which falls to the bottom when this acid is added to the metal in ſolution, it is probable hat the paleneſs produced by borax may ariſe from the combination of a ſmall portion of its acid with the gold, which might be driven off by a continuance of the heat; and unites by ſtronger affinity with he alkali of the nitre, or of the common ſalt, in proportion as their acids are diſſipated by heat.

— unchanged by earths, alkalis, or ſulphur.

Earths and alkalis do not act on gold in the dry way. Sulphur, which combines with moſt metals, has no effect on this. A proceſs called dry parting

Proceſs of dry parting.

is grounded on this property, and is more eſpecially uſed in ſeparating ſilver from gold, when the quantity of this latter metal is too ſmall to anſwer the charges of diſſolving the larger maſs of ſilver in nitrous acid. For this purpoſe, the mixed metal is fuſed, and flowers of ſulphur thrown on its ſurface. This combines with the ſilver in the form of a black ſcoria; while the gold remains at the bottom in its metallic ſtate. The operation of dry parting does not leave the gold in a ſtate of purity; becauſe the laſt portions of ſilver are defended from the action of the ſulphur. But when the quantity of ſilver is thus diminiſhed, the operation of parting with aqua fortis, or nitrous acid, may be advantageouſly uſed.

Combination with liver of ſulphur:

Liver of ſulphur diſſolves gold in the dry way. Equal parts of ſulphur and vegetable alkali are to be haſtily fuſed with one fourth of a part of gold leaf. This combination is ſoluble in water, with which it forms a yellowiſh green ſolution. By the addition of an acid the gold is thrown down in combination with the ſulphur; of which it may be deprived by heat.

— with metals.

Moſt metals unite with gold by fuſion. With ſilver it forms a compound, which is paler in proportion to the quantity of ſilver added. It is remarkable that a certain proportion, for example a fifth part, renders it greeniſh. From this circumſtance, as well as from that of a conſiderable proportion of theſe metals ſeparating from each other by fuſion, in conſequence of their different ſpecific gravities, when their proportions do not greatly differ, it ſhould ſeem that their union is little more than a mere mixture, without combination. For as gold leaf tranſmits the green rays of light, it will eaſily follow, that particles of ſilver, enveloped in particles of gold, will reflect a green inſtead of a white light.

Combinations with metals. Platina.

A ſtrong heat is neceſſary to combine platina with gold; it greatly alters the colour of the gold if its weight exceed the forty-ſeventh part of the maſs: it does not much affect the ductility. The Spaniſh miniſtry has prohibited the exportation of platina from America, leſt it ſhould be uſed in adulterating gold; but this does not appear to be a danger which need be feared, as chemiſtry has long been in poſſeſſion of ſeveral ſimple and expeditious methods of diſtinguiſhing this fraud, which beſides is evident to the ſight when the quantity of debaſement is conſiderable. It may be queſtioned, likewiſe, whether the value of platina would not ſoon exceed that of gold, if its properties and uſes were better known in ſociety.

Vide p. 227, and alſo chap. iii. of this ſection.

Mercury:

Mercury is ſtrongly diſpoſed to unite with gold in all proportions, with which it forms an amalgam: this, like other amalgams is ſofter, the larger the proportion of mercury. It ſoftens and liquefies by heat, and cryſtallizes by cooling.

— lead, copper, &c.

Lead unites with gold, and conſiderably impairs its ductility. Copper renders gold leſs ductile, harder, more fuſible, and of a deeper colour. This is the uſual addition in coin, and other articles uſed in ſociety. Tin renders it brittle in proportion to its quantity; but it is a common error of chemical writers to ſay that the ſlighteſt addition is ſufficient for this purpoſe. With iron it forms a grey mixture, which obeys the magnet. This metal is very hard, and is

Alchorne in Phil. Tranſ. vol. 75.

GOLD.

Combinations with metals.

ſaid to be much ſuperior to ſteel for the fabrication of cutting inſtruments. Biſmuth renders gold white and brittle; as do likewiſe nickel, arſenic, and antimony. Zinc produces the ſame effect; and, when equal in weight to the gold, a metal of a fine grain is produced, which is ſaid to be well adapted to form the mirrors of reflecting teleſcopes, on account of the fine poliſh it is ſuſceptible of, and its not being ſubject to tarniſh. The alloys of gold with the regulus of manganeſe or molybdena are not known. It could not be mixed with the regulus of wolfram, on account of the infuſibility of this laſt ſubſtance.

Native ores, or alloys of gold.

Gold is found moſtly in the metallic ſtate, though generally alloyed with ſilver, copper, iron, or all three. It is found either in ſeparate lumps, or viſible grains, among the ſands of rivers in many parts of Europe, and elſewhere. The quantity is for the moſt part inſufficient to pay the coſt of ſeparating it; but it is thought to be more univerſally diffuſed in ſands and earths than any other metal, except iron. The greateſt quantity of gold is imported into Europe from South America. Some is brought from the Eaſt Indian iſlands and China, and ſome from the coaſt of Africa. The principal gold mines in Europe are thoſe of Hungary. Some ſands afford gold by ſimple waſhing; the heavy metallic particles ſubſiding ſooneſt; but when it is bedded in earths or ſtones, theſe ſubſtances are pounded, and boiled with one tenth of their weight of mercury, together with water. The mercury, after a certain time, abſorbs the gold, and may be ſeparated by preſſure through leathern bags, and ſubſequent diſtillation. Or otherwiſe, if the ſand

Purification.

Auriferous ſands

ſand be heated red hot, and quenched in water ſeveral times, for the purpoſe of cracking and dividing it, and the whole be then melted into glaſs, with twice its weight of the calx of lead, called litharge, and charcoal powder be then added, the lead will be revived into the metallic ſtate, and will carry the gold along with it. By expoſure to a proper degree of heat, with acceſs of air, the lead may again be converted into litharge, and the gold will be left pure. This laſt operation is in fact a method of aſſaying ſands which contain gold, rather than of obtaining it from them in the large way.

Pyrites containing gold.

Gold is alſo found in certain martial pyrites in Sweden and elſewhere; from which it may be extracted by torrefaction, or burning of the ſulphur, and ſubſequent digeſtion in aqua regia.

Cupellation of gold.

To obtain gold in a ſtate of purity, or to aſcertain the quantity of alloy it may contain, it is expoſed to a ſtrong heat, together with lead, in a porous crucible. This operation is called cupellation, and is performed as follows: The precious metal is put, together with a due proportion of lead, into a ſhallow crucible made of burned bones, called a cupel; and the fuſion of the metals is effected by expoſing them to a conſiderable heat in a muffel, or ſmall earthen oven, fixed in the midſt of a furnace. The lead continually vitrifies, or becomes converted into a glaſſy calx, which diſſolves all the imperfect metals. This fluid glaſs, with its contents, ſoaks into the cupel, and leaves the precious metal in a ſtate of purity. During the cupellation, the ſcoriæ running down on all ſides of the metallic maſs, produce an

appear-

GOLD.

appearance called circulation; by which the operator judges whether the proceſs is going on well. When the metal is nearly pure, certain priſmatic colours flaſh ſuddenly acroſs the ſurface of the globule, which ſoon afterward appears very brilliant and clean: this is called the brightening, and ſhews that the ſeparation is ended.

Separation of gold from the perfect metals:

After gold has paſſed the cupel, it may ſtill contain either of the other perfect metals, platina or ſilver. The former is ſeldom ſuſpected; the latter is ſeparated by the operations called quartation and parting.

—by quartation:

Quartation conſiſts in adding three parts of ſilver to the ſuppoſed gold, and fuſing them together; by which means the gold becomes one fourth of the maſs only. The intention of this is to ſeparate the particles of gold from each other, ſo that they may not cover and defend the ſilver from the action of the pure nitrous acid, which is to be uſed in the proceſs of parting.

—and parting.

Parting conſiſts in expoſing the maſs, previouſly hammered, or rolled out thin, to the action of boiling aqua fortis of a due ſtrength. If the acid be not too concentrated, it diſſolves the ſilver, and leaves the gold in a porous maſs of the original form; but, if too ſtrong, the gold is in a powdery form, which may be waſhed and dried. The weight of the original metal before cupellation, and after all the ſubſequent ſtages, ſerves to aſcertain the degree of fineneſs of the ingot, or ore, of which it was a part.

Fineneſs of gold.

The quantity of alloy is never conſidered as part of the value of metals which contain either gold or ſilver. In eſtimating or expreſſing the fineneſs of gold, the whole maſs ſpoken of is ſuppoſed to weigh twenty-four carats of twelve grains each, either real or merely proportional, like the aſſayer's weights; and the pure gold is called fine. Thus, if gold be ſaid to be 23 carats fine, it is to be underſtood, that in a maſs weighing 24 carats the quantity of pure gold amounts to 23 carats.

The aſſay of ſmall work, by the touch.

In ſuch ſmall works as cannot be aſſayed by ſcraping off a part and cupelling it, the aſſayers endeavour to aſcertain its quality, or fineneſs, by the touch. This is a method of comparing the colour and other properties of a minute portion of the metal with thoſe of certain ſmall bars whoſe compoſition is known. These bars are called touch-needles; and they are rubbed upon the black baſaltes, which for that reaſon is called the touchſtone. Black flint, or pottery, will ſerve the ſame purpoſe. Sets of golden needles may conſiſt of—pure gold; pure gold 23½ carats, with half a carat ſilver; 23 carats gold, with one carat ſilver; 22½ carats gold, with 1½ carat ſilver; and ſo forth, till the ſilver amounts to four carats; after which the additions may proceed by whole carats. Other needles may be made in the ſame manner, with copper inſtead of ſilver; and other ſets may have the addition conſiſting either of equal parts ſilver and copper, or ſuch proportions as the occaſions of buſineſs require.

Touch-needles.

Obſervations on the aſſay by the touch.

In foreign countries, where trinkets and ſmall work are required to be ſubmitted to the aſſay of the touch, a variety of needles are neceſſary; but they are not much uſed in England. They afford however a degree of information which is more conſiderable than might at firſt be expected. The attentive aſſayer

3 not

Aſſay by the touch.

not only compares the colour of the ſtroke made upon the touchſtone by the metal under examination with that produced by his needle, but will likewiſe attend to the ſenſation of roughneſs, dryneſs, ſmoothneſs, or greaſineſs, which the texture of the rubbed metal excites when abraded by the ſtone. When two ſtrokes perfectly alike in colour are made upon the ſtone, he may then wet them with aqua fortis, which will affect them very differently if they be not ſimilar compoſitions: or the ſtone itſelf may be made red-hot by the fire, or by the blow-pipe, if thin black pottery be uſed; in which caſe the phenomena of calcination will differ according to the nature and quantity of the alloy.

Aſſay of gold ores in the moiſt way.

Gold ores may be aſſayed in the moiſt way by pounding them very fine, weighing a determinate portion, and attempting their ſolution in nitrous acid, which will diſſolve the matrix if it conſiſt of calcareous earth; or, if it be ſelenite, the powder may be digeſted in aqua regia as long as any metallic ſubſtance is taken up; after which the gold may be precipitated by an addition of vitriol of iron, which will cauſe it to fall down in the metallic ſtate.

Uſes of gold.

The principal uſe of gold is as the medium of exchange in coin; for which it has been choſen to occupy the firſt place, on account of its ſcarcity, its great weight, and its not being ſubject to tarniſh. The gold coins of Great Britain contain eleven parts of gold, and one of copper.

Gold is likewiſe uſed in gilding; for which purpoſe, as we have already ſhewn, it is mechanically divided into leaves of extreme thinneſs. Theſe are ſtuck upon wood, previouſly ſmeared with adheſive oil, or animal glue, called ſize. The proceſs called water-gilding, which is uſually applied to copper or braſs, is performed by immerſing the clean copper into a diluted ſolution of mercury. The copper is corroded by the acid, which at the ſame time depoſits a thin coating of mercury. This coating, after the piece is waſhed, facilitates the adheſion of an amalgam of gold, which is then to be rubbed upon it. The mercury is afterwards volatilized by heat; and the work is finiſhed by burning gilding wax upon it, which is a compoſition of red bole, verdigriſe, alum, and bees wax. The intention of this laſt application appears to be that of concealing the defects of the gilding.

Water-gilding.

There is another method of gilding, which is performed by ſteeping linen rags in a ſolution of gold. Theſe are afterwards dried and burned to aſhes, which contain gold in a very divided ſtate. Nothing more is neceſſary than to moiſten the end of a cork, and dip it in this burned matter, together with a little wood aſhes, and rub it upon the face of the ſilver intended to be gilded. By this means the gold eaſily adheres.

The other uſes of gold, in laces, &c. are ſufficiently known.

CHAP.

CHAP. II.

CONCERNING SILVER.

SILVER. Characters of ſilver.

SILVER is the whiteſt of all metals, conſiderably harder than gold, very ductile and malleable, but leſs malleable than gold; for the continuity of its parts begins to break when it is hammered out into leaves of about the hundred and ſixty thouſandth of an inch thick, which is more than one third thicker than gold leaf: in this ſtate it does not tranſmit the light. Its ſpecific gravity is moderate, being inferior to platina, gold, mercury, and lead. It ignites before melting, and requires a ſtrong heat to fuſe it. The heat of common furnaces is inſufficient to calcine it: but the heat of the moſt powerful burning lenſes vitrifies a portion of it, and cauſes it to emit fumes; which, when received on a plate of gold, are found to be ſilver in the metallic ſtate. It has likewiſe been partly calcined by twenty ſucceſſive expoſures to the heat of the porcelain furnace at Sêves. The air alters it very little; though it is diſpoſed to obtain a thin purple or black coating from the ſulphureous vapours which are emitted from animal ſubſtances, drains, or putrefying matters. This coating, after a long ſeries of years, has been obſerved to ſcale off from images of ſilver expoſed in churches; and was found, on examination, to conſiſt of ſilver united with ſulphur.

Silver

Solubility of ſilver in acids.

Silver is ſoluble in the vitriolic acid when concentrated and boiling, and the metal in a ſtate of diviſion. The marine acid ſcarcely acts upon it, unleſs dephlogiſticated: but the nitrous acid diſſolves it with great rapidity, and with a plentiful diſengagement of nitrous air; which, during its extrication, gives a blue or green colour to the acid, that entirely diſappears if the ſilver made uſe of be pure: if it contain copper, the ſolution remains greeniſh; and if the acid contain either vitriolic or marine acid, theſe combine with a portion of the ſilver, and form ſcarcely ſoluble compounds, which fall to the bottom. If the ſilver contain gold, this metal ſeparates in blackiſh coloured flocks. The nitrous acid diſſolves more than half its weight of ſilver; and the ſolution is very cauſtic, that is to ſay, it deſtroys and corrodes animal ſubſtances very powerfully. This action appears to depend on the ſtrong diſpoſition of the ſilver to become revived; by which it either attracts phlogiſton from thoſe ſubſtances according to the ancient theory, or communicates vital air to them according to the new theory: ſo that the animal ſubſtances undergo a proceſs equivalent to combuſtion.

Combination with nitrous acid.

The ſolution of ſilver, when fully ſaturated, depoſits thin cryſtals as it cools, and alſo by evaporation. Theſe are called lunar nitre, or nitre of ſilver. A gentle heat is ſufficient to fuſe them, and drive off their water of cryſtallization. In this ſituation it is of a black colour, may be caſt into ſmall ſticks in a mould, and then forms the lapis infernalis, or lunar cauſtic, uſed in ſurgery. A ſtronger heat decompoſes

lunar

SILVER. lunar nitre, the acid flying off, and the ſilver remaining pure. It is obvious that, for the purpoſe of forming the lunar cauſtic, it is not neceſſary to ſuffer the ſalt to cryſtallize, but that it may be made by evaporating the ſolution of ſilver at once to dryneſs; and as ſoon as the ſalt is fuſed, and ceaſes to boil, it may be poured out. The nitrous acid driven off from lunar nitre is decompoſed, the products being vital air and phlogiſticated air.

Lunar cauſtic.

Page 167, 168.

Although the nitrous acid diſſolves ſilver with ſuch great facility, it appears to do this only in conſequence of its great power to calcine the metal; for the vitriolic and marine acids have a greater attraction for the calx. They accordingly take it from that acid, and form ſalts; which, as we have already obſerved, fall to the bottom on account of their difficult ſolubility. The vitriol of ſilver, which is formed by pouring vitriolic acid into the nitrous ſolution of ſilver, is ſparingly ſoluble in water; and on that account forms cryſtals, which are ſo ſmall that they compoſe a white powder. The marine acid precipitates from nitrous acid the ſaline compound called luna cornea, or horn ſilver, which has been ſo diſtinguiſhed becauſe, when melted and cooled, it forms a ſemi-tranſparent and partly flexible maſs reſembling horn. It is ſuppoſed that a preparation of this kind has given riſe to the accounts of malleable glaſs.

Vitriol of ſilver.

Luna cornea.

Malleable glaſs.

If any ſalt with baſe of alkali, containing the marine acid, be added to the nitrous ſolution of ſilver, the ſame effect takes place by double affinity; the alkaline baſe uniting with the nitrous acid, and the ſilver alling down in combination with the marine acid.

Since

Very pure ſilver obtained from luna cornea.

Since the marine acid throws down only ſilver, lead, and mercury, and the latter of theſe two are not preſent in ſilver that has paſſed cupellation, though a ſmall quantity of copper may elude the ſcorification in that proceſs, the ſilver which may be revived from luna cornea is purer than can readily be obtained by any other means. When this ſalt is expoſed to a low red heat, its acid is not expelled; and a greater heat cauſes the whole concrete either to riſe in fumes, or to paſs through the pores of the veſſel. To reduce it, therefore, it is neceſſary that it ſhould be triturated with its own weight of fixed alkali and a little water, and the whole afterwards expoſed to heat in a crucible whoſe bottom is covered with mineral alkali; the maſs of luna cornea being likewiſe covered with the ſame ſubſtance. In this way the acid will be ſeparated from the ſilver, which is reduced to its metallic ſtate.

Teſt of marine acid in waters.

As the precipitate of luna cornea is very perceptible, the nitrous ſolution of ſilver is uſed as a teſt of the preſence of marine acid in waters; for a drop of this ſolution poured into ſuch waters will cauſe a very evident cloudineſs. The ſolution of ſilver is alſo uſed by aſſayers to purify the nitrous acid from any admixture of marine acid. In this ſtate they call it precipitated aqua fortis.

Purification of nitrous acid.

Precipitates.

The precipitates of ſilver which are formed by the addition of alkalis or earths, are all reducible by mere heat, without the addition of any combuſtible ſubſtance. The fulminating combination of volatile alkali with ſilver, exhibits one of the moſt aſtoniſhing inſtances

SILVER.

inſtances of chemical detonation hitherto known *.

Preparation of fulminating ſilver.

Pure ſilver is diſſolved in pale nitrous acid, and precipitated by the addition of lime-water. This calx, or precipitate, after decantation of the fluid, is to be dried by expoſure to the air for three days. The inventor thinks the preſence of light has ſome influence in the ſucceſs of the experiment. The dried calx being agitated or ſtirred in a ſolution of cauſtic volatile alkali, aſſumes the form of a black powder, from which the fluid is to be decanted, and the black ſubſtance left to dry in the air. This is the fulminating ſilver.

Its effects.

Gunpowder and fulminating gold are not to be compared with this new product; as the former requires ignition, and the latter a ſenſible degree of heat, to cauſe them to fulminate. But the ſlighteſt agitation or friction is ſufficient to cauſe the fulminating ſilver to explode. When it is once obtained, it can no more be touched. The falling of a few atoms of this preparation from a ſmall height produced the detonation; a drop of water falling upon it had the ſame effect. No attempts therefore can be made to incloſe it in a bottle; but it muſt remain in the capſule wherein, by evaporation, it obtained this terrible property.

Precautions.

To make this experiment with ſafety, it is proper to uſe no greater quantity than a grain of ſilver; the laſt deſiccation ſhould be made in a metallic veſſel; and the face of the operator ſhould be defended by

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* Diſcovered by Berthollet. See the Journal de Phyſique for June 1788, p. 474.

a maſk, with holes for the eyes defended with ſtrong glaſs.

Fulminating ſilver.

The volatile alkali made uſe of in converting the calx of ſilver into the black precipitate, was expoſed to ebullition in a ſmall matraſs of glaſs; and the fluid being then ſuffered to cool, the inſide of the veſſel became lined with ſmall cryſtals. When one of theſe was touched beneath the cold liquid, an exploſion took place, which broke the matraſs in pieces, and threw the liquid up to the ceiling of the laboratory.

Theory of the inventor, page 225:

The inventor's theory of theſe effects is the ſame as that of fulminating gold. The combination conſiſts of volatile alkali and calx of ſilver; that is to ſay, in the new theory, of inflammable air, phlogiſticated air, ſilver, and vital air. The ſlighteſt change of temperature or agitation diſpoſes the inflammable air to combine with the vital air, which adheres very feebly to the ſilver. Theſe form water, while the phlogiſticated air is diſengaged, and the ſilver reduced to the metallic ſtate. The exploſion depends on the ſudden tranſition of the phlogiſticated air and the water to the elaſtic ſtate by heat: but the change of capacity from which the heat ariſes has not yet been explained. On the phlogiſtic theory, it will be ſaid that the ſilver is revived by combining with the inflammable air, or phlogiſton of the alkali; while the phlogiſticated and vital air fly off in the exploſion.

— by the phlogiſtic hypotheſis.

Keir's compound acid, page 169.

It is a valuable diſcovery of Mr. Keir *, that a mixture of ſtrong vitriolic acid with the nitrous acid, or nitre, is a powerful ſolvent of ſilver, though it ſcarcely

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* Phil. Tranſ. 1780. p. 367.

acts upon the other metals. This is of conſiderable importance in the Birmingham manufactures, where the ſilver in the cuttings of plated copper is required to be ſeparated from this laſt metal. For this purpoſe the pieces of metal are put into a glazed earthen pan, and a compoſition of eight or ten pounds of oil of vitriol, with one pound of nitre, is poured upon them, ſtirred about, and the action of the fluid aſſiſted by a heat between 100° and 200° of Fahrenheit. When the liquor is nearly ſaturated, the ſilver is to be precipitated by common ſalt, which may be eaſily afterwards reduced; or, otherwiſe, the ſilver may be precipitated in its metallic ſtate by adding to the ſolution a few of the pieces of copper, and a ſufficient quantity of water, which enables the liquor to act on the copper. The theory of this effect ſtill remains to be inveſtigated.

Sulphur combines readily with ſilver in the dry way; but may be ſeparated by a ſtronger heat. The ſulphur of liver of ſulphur likewiſe blackens ſilver, and combines with it, whether the ſilver be immerſed in the liquid ſolution, or expoſed to hepatic air.

Action of aqua regia upon ſilver.

Aqua regia acts ſtrongly on ſilver; but precipitates it in the form of luna cornea as faſt as it is diſſolved. This effect may be eaſily underſtood by conſidering that the nitrous acid diſſolves the ſilver, and the marine precipitates it.

The neutral ſalts alone do not alter ſilver either in the moiſt or dry way; nitre, in particular, does not deflagrate with this metal.

Precipitation of ſilver by metals.

Moſt metallic ſubſtances precipitate ſilver in the metallic ſtate from its ſolution. The aſſayers make uſe of copper to ſeparate the ſilver from the nitrous acid uſed in the proceſs of parting. The precipitation of ſilver by mercury is very ſlow, and produces a peculiar ſymmetrical arrangement, called the tree of Diana. In this, as in all precipitations, the peculiar form may be affected by a variety of concomitant circumſtances; for which reaſon one proceſs uſually ſucceeds better than another. Lemery directs that an ounce of fine ſilver be diſſolved in a ſufficient quantity of very pure and moderately ſtrong nitrous acid; that this ſolution be mixed in a matraſs, or bottle, with about twenty ounces of diſtilled water; and that, after the addition of two ounces of mercury, the whole be ſuffered to repoſe. During the ſpace of forty days a kind of tree of ſilver will be formed on the ſurface of the mercury, with branches greatly reſembling a vegetable ſubſtance in its ramifications. The foregoing proceſs is ſaid by Macquer to ſucceed very well; but the following, of Homberg, is much ſhorter.

Tree of Diana.

Proceſs of Lemery.

Make an amalgam, without heat, of four drams of leaf ſilver, with two drams of mercury. Diſſolve this amalgam in four ounces, or a ſufficient quantity of pure nitrous acid of a moderate ſtrength; dilute this ſolution in about a pound and a half of diſtilled water; agitate the mixture, and preſerve it for uſe in a glaſs bottle, with a ground ſtopper. When this preparation is to be uſed, the quantity of one ounce is put into a phial, and the ſize of a pea of an amalgam of gold or ſilver, as ſoft as butter, is to be added; after which the veſſel muſt be left at reſt. Soon afterwards ſmall filaments appear to iſſue out of the ball

Homberg's proceſs for making the tree of Diana.

ball of amalgam, which quickly increaſe, and ſhoot out branches in the form of ſhrubs.

Theoretical obſervations.

In the above experiment of Lemery the nitrous acid depoſits its ſilver at the ſame time that it takes up mercury; and, in conſequence of the liquor being ſo much diluted, the proceſs goes on ſlowly, and the precipitated ſilver has time to arrange itſelf according to the law of its cryſtallization, whether that depend on the polarity of its particles, or on any other property not yet explained. In the method of Homberg there are two circumſtances which appear calculated to forward the proceſs: in the firſt place, the nitrous acid already contains mercury in ſolution, which may probably render it more diſpoſed to part with the ſilver; and, in the next place, the mercury is combined with ſilver or gold in the form of an amalgam. Theſe may perhaps facilitate the precipitation of the ſilver, by preſenting a baſe for it to combine with; which may be more perfectly at repoſe, becauſe leſs agitable than the fluid mercury in the former experiment. After all, however, though the general theory of the experiment is not difficult, yet it does not ſeem eaſy to point out the effectual cauſe of the differences between the two reſults.

Page 81.

Combinations of ſilver; with gold:

Silver unites with gold by fuſion, and forms a pale alloy, as has been already mentioned in treating of that metal. With platina it forms a hard mixture, rather yellower than ſilver itſelf, and of difficult fuſion. The two metals do not unite well. Silver melted with one tenth part of crude platina, from which the ferruginous particles had been ſeparated by a ſtrong magnet, could not be rendered clear

— with platina:

clear of ſcabrous parts, though it was repeatedly fuſed, poured out, and laminated between rollers. It was then fuſed, and ſuffered to cool in the crucible, but with no better ſucceſs. After it had been formed, by rolling and hammering, into a ſpoon for blow-pipe experiments, it was expoſed to a low red heat, and became rough, and bliſtered over its whole ſurface. The quantities were one hundred grains of ſilver, and ten grains of platina. Nitre was added during the fuſions.

Combinations of ſilver with mercury:

Silver very readily combines with mercury. A very ſenſible degree of heat is produced when ſilver leaf and mercury are kneaded together in the palm of the hand. With lead it forms a ſoft maſs, leſs ſonorous than pure ſilver. With copper it becomes harder and more ſonorous, at the ſame time that it remains ſufficiently ductile: this mixture is uſed in the Britiſh coinage. Fifteen parts of ſilver, alloyed with one of copper, form the compound called ſtandard ſilver. The mixture of ſilver and iron has been little examined. With tin it forms a compound which, like that of gold with the ſame metal, has been ſaid to be brittle, however ſmall the proportion; though there is probably as little foundation for the aſſertion in the one caſe as in the other. With biſmuth, arſenic, zinc, and antimony, it forms brittle compounds. It does not unite with nickel. The compound of ſilver and wolfram, in the proportion of two of the former to one of the latter, was extended under the hammer during a few ſtrokes; but afterwards ſplit in pieces.

—with lead:

—with copper:

—with tin, &c.

SILVER.

Native ſilver and its ores.

Silver is found either native or mineralized. The native ſilver is found in Peru, and various parts of Europe; ſometimes in conſiderable maſſes, and often diffuſed through ſand, ochre, or lime-ſtone. It is ſeldom pure, but is generally alloyed with copper, and ſometimes with gold, iron, or regulus of antimony. The mineralized ſilver contains ſulphur and arſenic, or both, with other admixtures.

Purifying of native ſilver.

Native ſilver may be purified by pounding or waſhing, or amalgamation with mercury; and the ſilver itſelf is refined by cupellation with lead in the ſame manner as gold. In the large way, the litharge, or vitrified lead, is blown from the ſurface of the ſilver by bellows, inſtead of ſoaking into the crucible. Gold may be ſeparated from ſilver by parting with aqua regia, or treatment with ſulphur in the dry way, which combines with the ſilver, and leaves the gold diſengaged.

Vitreous ore of ſilver.

The vitreous ſilver ore is the richeſt ore of ſilver, and contains from ſeventy to eighty pounds of ſilver in the hundred weight; the reſt being ſulphur, with rarely any other metal, except a ſmall portion of iron. It is found either in ſolid large lumps, or inherent in quartz or ſpar. Its colour generally reſembles that of lead; but grows dark by expoſure to the air. It uſually poſſeſſes a ſlight degree of malleability, and is ſufficiently ſoft to be cut by a knife.

Analyſis in the moiſt way:

To analyſe this ore in the moiſt way, it may be boiled in nitrous acid, which acidifies the ſulphur, and cauſes great part to fly off in the form of vitriolic acid air. Common ſalt, or marine acid, will precipitate the ſilver in the form of luna cornea, which may be either reduced or accounted for by deducting one fourth of its weight when waſhed and dried, which fourth of its weight is marine acid.

— in the dry way.

In the dry way, it may be reduced by expoſing it to a heat not ſufficient to melt it. In this way the ſulphur is diſſipated, and the ſilver remains uſually in a fibrous form. Small portions may be conveniently decompoſed in this manner by the blow-pipe upon charcoal.

Red ſilver ore.

The red ſilver ore is a heavy ſhining ſubſtance, either tranſparent or opake; ſometimes grey or blackiſh, but always reddiſh when powdered: it uſually contains more than half, and ſometimes $\frac{3}{4}$ of its weight of ſilver, the reſt being arſenic and ſulphur.

Analyſis in the moiſt way.

In the moiſt way, this ore is analyſed by reducing it to fine powder, and boiling it with diluted nitrous acid. The reſidue, which contains the ſulphur and the arſenic, muſt be edulcorated with water; and the arſenic may be diſſolved by boiling in a ſufficient quantity of aqua regia If the ſulphur ſhould retain any luna cornea, it may be ſeparated by keeping it for ſome days in a cloſed veſſel, with its own weight of diluted cauſtic volatile alkali. The clear nitrous ſolution being mixed with the water uſed in the eduſcoration, affords a precipitate of luna cornea by the addition of ſea ſalt, which may either be reduced or accounted for in the ſame manner as in the aſſay of the vitreous ſilver ore.

White ore of ſilver analyſed.

Silver united with ſulphur, arſenic, and copper, is generally called the white ore of ſilver. One hundred grains of this being reduced to a powder, and gently boiled for an hour in more than twelve times its weight of diluted nitrous acid, the copper and ſilver are diſſolved, and a white reſiduum remains. The ſilver is precipitated in the metallic form by the immerſion of a clean plate of copper; and the copper being afterwards precipitated by the addition of volatile alkali, may be accounted for by allowing 194 grains of the precipitate to one hundred of the copper, and deducting the loſs ſuſtained by the plate of copper which was immerſed in the ſolution. The white reſiduum may be deprived of its arſenic and iron by boiling in marine acid. The arſenic may be precipitated by the addition of water; and afterwards the iron, if any, by Pruſſian alkali. The undiſſolved ſulphur may be treated with volatile alkali, to try whether it contains either copper or luna cornea.

The other ores of ſilver, of which there is conſiderable variety, may be analyſed by varying the proceſſes according to the ſuppoſed or known general contents of the ore *.

Method of aſſaying ſilver, or its ores, in the dry way.

Sulphureous and arſenical ſilver ores may be aſſayed by roaſting and ſubſequent fuſion with a greater or leſs quantity of flux. In the fuſion, the ſilver is obtained alloyed with lead, copper, or iron, which may be ſeparated by cupellation with lead, and the ſilver left pure. The fineneſs of ſilver is denoted by the aſſayers, by mentioning the number of pennyweights and grains of pure ſilver contained in the ounce. So

See page 231.

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* For which conſult Bergman's Treatiſe on the Art of Aſſaying in the Humid Way, inſerted in the 2d vol. of the Engliſh tranſlation of his Opuſcula, or Eſſays.

that if an ounce of ſilver be found to loſe half a pennyweight by cupellation, it is ſaid to be eleven pennyweights twelve grains fine; if it loſe a whole pennyweight, it is ſaid to be eleven pennyweights fine, &c. Silver is likewiſe tried by the touch, in the ſame manner as gold. For this purpoſe, the aſſayers are provided with a ſet of needles or ſmall bars; the firſt of which contains $\frac{1}{16}$ part of its weight of copper, and the reſt ſilver; the ſecond contains $\frac{2}{16}$ parts of opper; the third $\frac{3}{16}$ parts; and ſo on to the laſt, which contains 15 parts of copper to one of ſilver. By the reſemblance of colour on the touchſtone, an ſtimate may be made of the fineneſs of the ſilver to omething nearer than the 30th part of the whole, which is a conſiderable acquiſition in the examination of ſmall articles, ſuch as rings, trinkets, and the like. It is true indeed that the uſe of the touch ſuppoſes he precious metal to be alloyed with copper only, which may not be the caſe; and conſequently the ſſayer is liable to be deceived in this reſpect: but he may in this caſe have recourſe to aqua fortis, or the blow-pipe, in the ſame manner as directed in the oregoing chapter.

Page 233, 234.
Aſſay of ſilver by the touch.

In the large works, where ſilver is extracted, the proceſſes are grounded on the properties already deſcribed. Native ſilver is triturated with mercury; fter which the amalgam is waſhed, to ſeparate the arthy particles; and the quickſilver ſeparated, partly y preſſure in leathern bags, and partly by diſtillation n iron retorts.

Extraction of ſilver from ores in the large way, by amalgamation:

Rich ſulphureous ores are roaſted, and fuſed with ead, to refine the ſilver by cupellation. The poorer ores,

— by fire.

ores, which contain copper, are fuſed with pyrites, which affords a maſs conſiſting of copper, ſulphur, and ſilver. Lead is then added, and the maſs treated in the way of eliquation. The lead flows out, carrying the ſilver with it; and, laſtly, theſe two metals are ſeparated by the teſt, on which the lead is converted into litharge, and the ſilver remains pure.

Uſes of ſilver.

The uſes of ſilver are well known: it is chiefly applied to the forming of various utenſils for domeſtic uſe, and as the medium of exchange in money. Its diſpoſition to aſſume a black colour by tarniſhing, and its ſoftneſs, appear to be the chief objection to its uſe in the conſtruction of graduated inſtruments for aſtronomical and other purpoſes, in which a good white metal would be a deſirable acquiſition.

CHAP. III.

CONCERNING PLATINA.

PLATINA.

Characters of platina.

PLATINA is one of the metals for the diſcovery of which we are indebted to our cotempora-ies. It has yet been found only in Spaniſh merica, among the gold mines there. We receive in the form of ſmall particles, from the minuteſt ze up to that of a pea; though theſe laſt are very ldom met with. Its particles or grains are ſmooth, regularly figured with round edges, and are flattened, robably by hammering in the mills in which the old is amalgamated. Theſe grains are of a whiter olour than iron, and are conſiderably malleable. In e ſtate in which we receive them, they are often mix-l with ferruginous ſand, which may be ſeparated by e magnet; and alſo with grains of quartz or cryſtal. Vhen it is ſeparated from heterogeneous particles, e crude platina itſelf is ſlightly magnetic, and is etween ſixteen and eighteen times as heavy as water. he moſt violent fires are inſufficient to melt it, ough its parts may be made to cohere together into ſolid button by the ſtrong heat of a wind furnace. urning lenſes of the moſt powerful kind fuſe it, and onvert it into a malleable metal; and ſmall portions f crude platina may be eaſily melted upon charcoal, y flame urged by a ſtream of vital air.

Crude platina.

Pure platina.

Pure or refined platina is by much the heavieſt ody in nature. It is very malleable, though conſiderably

Characters of platina.

derably harder than either gold or ſilver; and it harden much under the hammer. Its colour on the touchſtone is not diſtinguiſhable from that of ſilver. Whe in the higheſt degree of purity, it is not magnetical; but when its ſpecific gravity is as low a 21.36 it contains iron ſufficient to render it magnetical. Pure platina requires a very ſtrong heat t melt it; but when urged by a white heat, it is ſai that its parts will adhere together by hammering This property, which in iron is diſtinguiſhed by th name of welding, is peculiar only to platina and tha metal, which reſemble each other likewiſe in thei infuſibility.

Welding.

Solution in dephlogiſticated marine acid:

Platina is not altered by expoſure to air; neither i it acted upon by the moſt concentrated ſimple acid even when boiling, or diſtilled from it. The dephlogiſticated or aërated marine acid diſſolves it, as doe likewiſe aqua regia; and both are ſaid to form th ſame ſalts with it. In this particular of ſolubilit platina reſembles gold.

— in aqua regia.

The aqua regia beſt adapted to the ſolution o platina is compoſed of equal parts of the nitrous an marine acids. The ſolution does not take place wit rapidity. A ſmall quantity of nitrous air is diſengaged; the colour of the fluid becoming firſt yellow and afterwards of a deep reddiſh brown, which, upo dilution with water, is found to be an intenſe yellow This ſolution is very corroſive, and tinges anima matters of a blackiſh brown colour: it affords cryſtals by evaporation. The metal is precipitable fro its ſolution by ſal ammoniac; a property by which i is diſtinguiſhed from all other metals, in the ſam

Diſtinctive character.

mann

Separation of gold from platina.

nanner as the ſolution of gold is characterized by its recipitation upon the addition of martial vitriol. In his way, a compound ſolution of gold and platina ay be ſeparated by precipitating either of the two etals at pleaſure. The orange-coloured precipitate f platina, obtained by means of ſal ammoniac, is a aline ſubſtance, completely ſoluble in water; but its omponent parts have not been well aſcertained. It s fuſible without addition by a good forge furnace, nd forms a brilliant, denſe, and cloſe-grained button, hich is not malleable, probably on account of part f the ſaline ſubſtance not being diſſipated. The ame precipitate, expoſed to the ſtronger heat of a laſt furnace, was fuſed into a perfectly malleable egulus *.

Malleable platina.

Precipitates.

Alkalis and the ſoluble earths precipitate platina in he form of a calx from its ſolution. The Pruſſian lkali hereafter to be deſcribed does not precipitate t as it does all other metals; but it throws down plentiful blue precipitate, conſiſting of iron, which as contained in the Pruſſian blue. This property herefore affords a method of ſeparating the iron rom platina, which always contains it. The vola-

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* By the Count de Milly. See Magellan's Cronſtedt, page 74.—I have ſeveral ſmall ſpecimens of this platina, which is n thin plates or bars; their ſpecific gravity is above $21\frac{1}{2}$; in hich I do not pretend to a greater accuracy than $\frac{1}{200}$th part of he weight, becauſe the quantities are ſo ſmall. It is perfectly alleable, hard, and elaſtic, and obeys a ſtrong magnet when he pieces are floated upon water: one ſmall piece which was uſed by Parker's lens is not at all magnetical, and ſeems to exced 22 in ſpecific gravity.

tile alkali precipitates platina of an orange yellow colour. Neutral ſalts, with baſe of fixed alkali, do nc precipitate it.

Precipitates.

Moſt of the metals precipitate platina from its ſolution; but it does not in general fall down in th metallic ſtate.

This metal is not affected in the dry way by ſaline ſubſtances. Calx of arſenic facilitates its fuſion and the ſemi-metal forms a brittle compound wit the platina. Mr. Achard ſucceeded in making crucibles of platina, by fuſing equal parts of platina, whit arſenic, and vegetable alkali. This matter, whe cooled, was reduced to a powder, and rammed int the mould of the veſſel intended to be formed. A ſtrong heat, quickly raiſed, and continued for ſom time, fuſed the maſs; and, after diſſipating the arſeni and the alkali, left the platina in the form deſired.

Crucibles of platina.

Combinations of metals.

Platina does not readily combine with gold, excep by a ſtrong heat; and it greatly debaſes the colour o that metal: it does not readily unite with ſilver; t which however it communicates part of its hardneſs, while it impairs its colour and brilliancy. I altogether reſiſts the action of mercury; or at leaſ this mutual action does not ſeem to be ſtronger tha that of mercury and iron. Lead and platina unit very well by fuſion; the lead becomes much leſ ductile, and even brittle, according to the proportions of the platina. In the attempts to cupel platina wit lead, the proceſs went on as it does uſually with ſilve and gold in the beginning; but as ſoon as a conſiderable portion of the lead was diſſipated, the platin fixed, and the operation ceaſed. But with a ſtronge heat

Cupellation.

Combinations with metals.

heat, ſuch as that of a porcelain furnace, the operation may be completed, and malleable platina obtained free from lead. It has not been united with forged iron; but with caſt iron it formed a brittle compound. With copper it melts with conſiderable facility; and in due proportions forms a compound which takes a very beautiful poliſh, and is not ſubject to tarniſh: this has been uſed for the mirrors of reflecting teleſcopes. Tin and platina melt very eaſily, and form a compound, ſcarcely ductile when the tin abounds, but very brittle when the platina predominates. Biſmuth and antimony unite with platina by fuſion, and form brittle compounds, which do not promiſe to be of any conſiderable utility. Zinc likewiſe combines readily with it, and renders it very fuſible; this alloy is brittle, hard, and of a blueiſh colour. Wolfram can ſcarcely be brought to ſhew any ſign of union with platina. Cobalt, manganeſe, and molybdena have not been tried.

CHAP. IV.

CONCERNING MERCURY.

MERCURY.

Characters of mercury.

MERCURY is diſtinguiſhed from all other metals by its extreme fuſibility, which is ſuch that it does not take the ſolid ſtate until cooled to the thirty-ninth degree below o on Fahrenheit's thermometer; and of courſe it is always fluid in the temperate climates of the earth. Its colour is white, and rather bluer than ſilver. In the ſolid ſtate it is malleable *; its ſpecific gravity is greater than that of any of the other metals, platina, gold, and wolfram excepted. It is volatile, and riſes in ſmall portions at the common temperature of the atmoſphere, as is evinced by ſeveral experiments, more eſpecially in a vacuum, ſuch as obtains in the upper part of a barometer tube. At the temperature of about ſix hundred degrees it boils rapidly, and riſes copiouſly in fumes. Few of the other metals melt at ſo low a temperature as the boiling point of mercury. When expoſed to ſuch a heat as may cauſe it to riſe quickly in the vaporous form, it gradually becomes converted into a red calx, provided vital air be preſent. This is known by the name of precipitate per ſe. A greater heat however revives this metallic calx, at the ſame time that the vital air is again extricated.

Precipitate per ſe.

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* The reader will find an ample account of the freezing of quickſilver in Dr. Blagden's Hiſtory, Vol. LXXIII. of the Philoſophical Tranſactions.

Characters.

Mercury is not perceptibly altered by expoſure to the air; though by long agitation, with acceſs of air, it becomes converted into a black powder or calx, which gives out vital air by heat, the metal being at the ſame time revived. This metal is diſpoſed to attract moiſture; and cannot, for that reaſon, be uſed in the conſtruction of barometers and thermometers until it has been firſt boiled in an open veſſel for the ſpace of about half an hour.

Electric light.

When mercury is agitated in a dry glaſs bottle, the friction between the metal and the glaſs produces electricity. If the bottle be imperfectly exhauſted, this electricity paſſes into the vacuum, and produces a light which was formerly thought to be a proof of the perfection of the vacuum in the upper part of barometer tubes; but which in fact does not appear in ſuch barometers as have been cleared of air by careful boiling in the tube.

Action of vitriolic acid on mercury.

The vitriolic acid does not act on this metal, unleſs it be well concentrated and boiling. For this purpoſe, mercury is poured into a glaſs retort, with near twice its weight of vitriolic acid. As ſoon as the mixture is heated, a ſtrong effervcſcence takes place, vitriolic acid air eſcapes, the ſurface of the mercury becomes white, and a white powder is produced; when the vitriolic air ceaſes to come over, the mercury is found to be converted into a white, opake, cauſtic, ſaline maſs, at the bottom of the retort, which weighs one third more than the mercury, and is decompoſed by heat. Its fixity is conſiderably greater than that of mercury itſelf. If the heat be raiſed, it gives out a

conſi-

MERCURY.

conſiderable quantity of vital air, the mercury being at the ſame time revived.

Vitriol and calx of mercury.

The white maſs produced by the action of vitriolic acid upon mercury, conſiſts partly of a ſaline maſs, or vitriol of mercury, and partly of a calx, or mercury united to vital air (ſimply, according to the new theory; or deprived of phlogiſton, according to the old theory, which phlogiſton is ſuppoſed to enter into the combination of the vitriolic acid air). Water ſeparates the ſalt from the calx, which laſt is then of a yellow colour. Much waſhing is required to produce this colour, if cold water be uſed; but if a large quantity of hot water be poured on, the calx immediately aſſumes a bright lemon colour. In this ſtate, it is called turbith mineral.

Turbith mineral.

The vitriol of mercury affords a ſalt by evaporation, in ſmall needle-formed deliqueſcent cryſtals. The addition of a large quantity of water, more eſpecially if heated, decompoſes vitriol of mercury, which depoſits turbith mineral, unleſs there be an exceſs of acid in the fluid.

Precipitates.

The fixed alkalis, magneſia, and lime, precipitate mercury from its ſolution: theſe precipitates are reducible in cloſed veſſels by mere heat without addition.

Solution in nitrous acid.

Page 164.

The nitrous acid rapidly attacks and diſſolves mercury, at the ſame time that a large quantity of nitrous air is diſengaged; and the colour of the acid becomes green during its eſcape. Strong nitrous acid takes up its own weight of mercury in the cold; and this ſolution will bear to be diluted with water. But if the ſolution be made with the aſſiſtance of heat, a much larger quantity is diſſolved; and a precipitate of calx will be afforded by the addition of diſtilled water, which is of a yellow colour if the water be hot, or white if it be cold, and greatly reſembles the turbith mineral produced with vitriolic acid: it has accordingly been called nitrous turbith. If acid be added to the ſolution made with heat, it loſes its property of being decompoſed by water. This decompoſition is not complete, but only deprives the acid of the redundant calx.

Nitrous turbith.

All the combinations of mercury and nitrous acid are very cauſtic, and form a deep purple or black ſpot upon the ſkin. They afford cryſtals, which differ according to the ſtate of the ſolution. When nitrous acid has taken up as much mercury as it can diſſolve by heat, it uſually aſſumes the form of a white ſaline maſs. When the combination of nitrous acid and mercury is expoſed to a gradual and long continued low heat, it gives out a portion of nitrous acid, and becomes converted into a red ſubſtance, ſimilar in all reſpects to the red calx of mercury formed by ſimply heating it in contact with vital air. This is known by the name of red precipitate.

Mercurial nitre.

Red precipitate:

When red precipitate is ſtrongly heated, a large quantity of vital air is diſengaged, together with ſome phlogiſticated air, and the mercury is ſublimed in the metallic form.

—decompoſed.

Mercurial nitre is more ſoluble in hot than cold water, and affords cryſtals by cooling. It is decompoſed by the affuſion of a large quantity of water, unleſs the acid be in exceſs.

When mercury is diſſolved in nitrous acid by means of heat, nitrous air is emitted at firſt; and after-

MERCURY.

Nitrous ſolution.

wards it ceaſes, though the ſolution ſtill proceeds. The mercury which is taken up during the firſt part of the proceſs is calcined, and the other portion is diſſolved in the metallic ſtate. If the ſolution be ſtopped in the firſt part of the proceſs, fixed and volatile pure alkalis precipitate the yellow calx; but if the ſolution be continued after the eſcape of the elaſtic fluid has ceaſed, the precipitate obtained by the ſame means is black, on account of the admixture of metallic mercury, which may be ſeparated from the yellow calx by diſtillation.

Precipitates.

Ponderous earth, magneſia, and lime, precipitate the nitrous ſolutions of mercury; and theſe precipitates, as well as all the other calces of this metal, are reducible by heat alone without addition.

Exploſion of mercurial precipitates.

The precipitates of mercury from acids, by means of alkalis, poſſeſs the property of exploding when expoſed to a gradual heat in an iron ſpoon, after having been previouſly triturated with $\frac{1}{6}$ of their weight of flowers of ſulphur. The reſidue conſiſts of a violet-coloured powder, which is converted by ſublimation into cinnabar. It ſeems therefore as if the ſulphur combined ſuddenly with the mercury, and expelled vital air in the elaſtic ſtate.

Decompoſition of the nitrous ſolution by other acids.

The vitriolic acid, or the ſalts containing it, decompoſe the nitrous ſolutions of mercury by virtue of the ſtronger attraction of the vitriolic acid to the metal. The precipitate which falls down does not eſſentially differ from the ſubſtance produced by the direct ſolution of mercury in the vitriolic acid. The marine acid likewiſe ſeizes the mercury diſſolved in the nitrous acid, and forms a compound which

Page 257.

which falls to the bottom. This conſiſts of a very cauſtic ſalt, which is called corroſive ſublimate, and is produced when the nitrous ſolution contains only calx of mercury; but when that ſolution is ſaturated with metallic mercury, the compound which falls down by the addition of marine acid is called white precipitate, and does not differ from the preparation which, when made in the dry way, is called calomel, or mercurius dulcis.

Corroſive ſublimate.

Page 263. Calomel.

The acetous and moſt other acids combine with the calx of mercury, and precipitate it from its ſolution in the nitrous acid.

The marine acid does not act perceptibly upon mercury in the metallic ſtate; but the dephlogiſticated or aërated marine acid readily diſſolves it, and forms the ſame combination as ariſes from the direct union of marine acid with calx of mercury; that is to ſay, corroſive ſublimate.

Combination of mercury with dephlogiſticated marine acid.

The great ſpecific gravity of mercury rendered it an object of peculiar attention to the alchemiſts and earlier chemiſts; many of whom hoped to fix it in the form of a ſolid ſubſtance, or to extract gold from it. From theſe motives, a great variety of proceſſes have been made with it, by methods which are much leſs direct and ſimple than thoſe of modern chemiſtry. Among others, the combination of the calx of mercury with marine acid is produced by ſeveral methods in the dry way by ſublimation. In the large way, corroſive ſublimate is prepared by triturating equal parts of mercury, common ſalt, and vitriol together, and expoſing the whole to a moderate heat. The corroſive ſublimate riſes, and adheres to the upper part of the glaſs veſſel.

Preparation of corroſive ſublimate.

Corroſive ſublimate.

veſſel. In this operation, the vitriolic acid from the vitriol is ſuppoſed to calcine the mercury, or to dephlogiſticate the marine acid of the common ſalt; in either of which caſes the compound of marine acid with calx of mercury will be formed. From this theory, it will eaſily be underſtood that corroſive ſublimate may be prepared by various methods. If the white maſs or calx of mercury, produced by expoſing that metal to the action of vitriolic acid, be heated in a matraſs with an equal quantity of common ſalt, this ſublimate will be had by double affinity; the vitriolic acid partly ſaturating the alkali, and the marine acid uniting with the calx of mercury, and riſing by ſublimation. In the ſame manner, the nitrous mercurial ſalt, or the mercurial precipitates, may be uſed inſtead of the calx of mercury by vitriolic acid.

Page 257.

Cauſticity of metallic ſalts.

As the cauſticity of metallic ſalts depends chiefly on the diſpoſition of the calcined metal to reſume the metallic ſtate, at the ſame time that it burns or calcines the ſubſtance to which it may be applied; it is accordingly found that corroſive ſublimate poſſeſſes this property in the moſt eminent degree; it is therefore one of the moſt active mineral poiſons. This ſalt is ſoluble in water, though ſparingly, and alſo in ardent ſpirit. It is precipitated of an orange colour by fixed alkalis. The abſorbent earths likewiſe throw down its calx. Volatile alkali affords a white precipitate, which ſoon afterwards aſſumes a ſlate colour.

Sal alembroth.

Corroſive ſublimate becomes much more ſoluble in water by the addition of ſal ammoniac, with which it forms a triple compound, called ſal alembroth by the alchemiſts, which cryſtallizes by cooling. The addition of a fixed alkali throws down a white calx of mercury, called white precipitate in the diſpenſatories.

White precipitate.

Preparation of calomel, or mercurius dulcis.

The preparation of calomel is uſually made by triturating corroſive ſublimate in a glaſs mortar with fluid mercury, added by a little at a time, until no more can be made to diſappear. A ſmall quantity of water added to the corroſive ſublimate during this part of the proceſs, prevents that ſalt from riſing in the form of noxious duſt. In this ſtate, the combination is the ſame as that obtained from the ſaturated nitrous ſolution of mercury by the addition of marine acid. The mixture of corroſive ſublimate and mercury is more perfectly combined by expoſing it to ſublimation. It adheres to the internal part of the ſubliming veſſel in the form of a white maſs, of a ſtriated texture. If there be any ſuſpicion of its containing corroſive ſublimate, which is not probable on account of the more volatile nature of the latter, they may be ſeparated by means of warm water, the calomel being inſoluble.

Page 261.

Butter of antimony.

When one part of antimony, which is the native combination or ore of antimony with ſulphur, is triturated or accurately mixed with two parts of corroſive ſublimate, and expoſed to diſtillation, the dephlogiſticated or aërated marine acid combines with the regulus of antimony, and riſes in the form of the compound called butter of antimony; while the ſulphur combines with the mercury, and forms cinnabar. If the regulus of antimony be uſed inſtead of the mineral, the reſidue which riſes laſt conſiſts of running mercury, inſtead of cinnabar.

MERCURY. Mercurial ethiops.

Mercury combines very readily with ſulphur. By trituration in a mortar the mercury diſappears, and forms a black compound with the ſulphur, which is called ethiops mineral, or mercurial ethiops. The combination is more ſpeedily made by mixing fluid mercury with melted ſulphur. In this way three parts of flowers of ſulphur unite with one of mercury. If the ſulphur be ſet on fire, the greateſt part burns, and the remainder is of a violet colour when pulverized. This conſiſts of a more intimate combination of mercury and ſulphur. It riſes in a heat nearly approaching to redneſs; and the ſublimate, which is called cinnabar, contains about $\frac{1}{5}$ part ſulphur, and the reſt mercury. The pigment called vermilion conſiſts of artificial cinnabar reduced to a powder.

Cinnabar or vermilion formed in the dry way:

Livers of ſulphur are decompoſed in the humid way by mercury, which unites with the ſulphur. With the fixed alkaline livers of ſulphur it forms a black powder, or ethiops, by agitation, which in the courſe of a number of years becomes red; but the volatile alkaline hepar, or fuming liquor of Boyle, converts mercury into a fine cinnabar in a very ſhort time. Turbith mineral, and the precipitates of mercury, are likewiſe converted into cinnabar by this alkaline hepar.

— in the humid way.

Unguents, &c.

Mercury unites by trituration with oils and mucilages, with which it forms black or deep blue compounds. A ſmall part of the mercury in theſe ſeems to be in combination, and the reſt in a ſtate of extreme diviſion.

This metal can ſcarcely be exhibited in the dry way, on account of its volatility. The degree of heat required

MERCURY. Page 256.

quired to convert it into the red calx called precipitate per ſe, is rather lower than its boiling point, and a greater reduces it again to the metallic ſtate. The calcination and reduction of mercury, without ddition, afford one of the ſtrongeſt arguments in avour of the ſyſtem which rejects phlogiſton.

Red calx of mercury, or precipitate per ſe.

In the production of the red calx of mercury, it is equired that air be preſent, and the metal kept in a tate of briſk evaporation. On this account it is found onvenient that the veſſel ſhould be ſo deep, and its perture ſo ſmall, that the fumes may not make their ſcape. It may be inferred that in this, as well as ther calcinations, there is an abſorption of vital air; nore eſpecially as vital air is expelled from the calx by eat *. When the experiment is made in cloſed veſſels y means of a body of the kind marked C, fig. 15, hoſe neck is introduced beneath a jar containing ommon air over mercury, the vital part is abſorbed, nd phlogiſticated or foul air remains; and afterwards, y an augmentation of heat, the mercury is revived, t the ſame time that it reſtores the conſtitution of the r by the emiſſion of the vital air. Ten days or a rtnight's conſtant heat is required to convert a few rains of mercury into precipitate per ſe in the ſmall ay.

Page 93.

Amalgams.

Mercury being habitually fluid, very readily comnes with moſt of the metals, to which it commuicates more or leſs of its fuſibility. When theſe etallic mixtures contain a ſufficient quantity of mer-

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[*] Lavoiſier, Traité Elémentaire de Chimie, page 35.

cury to render them ſoft at a mean temperature, they are called amalgams.

Combinations of metals.

It very readily combines with gold, ſilver, lead, tin, biſmuth, and zinc; more difficultly with copper, arſenic, and regulus of antimony; and ſcarcely at all with platina or iron: it does not unite with nickel or cobalt; and its action on mangane ſe, wolfram, and molybdena, is not known. Looking-glaſſes are covered on the back ſurface with an amalgam of tin. In this operation, mercury is poured on tin foil, upon a flat ſtone, and ſpread with a feather till its union with the tin has brightened every part of its ſurface. A large quantity of mercury is then poured on, and the glaſs is ſlided along the fluid ſurface; upon which it is afterwards preſſed by weights, to exclude the ſuperfluous mercury.

Native mercury and its ores.

Mercury is found native in ſlaty or quartzoſe earths, or viſibly diffuſed through maſſes of clay or ſtone. Native precipitate per ſe, or calx of mercury, has alſo been found; and this metal has likewiſe been met with in combination with the vitriolic and marine acids. Its volatility may probably have cauſed it to be overlooked in many minerals that may contain it. The greateſt quantity of mercury is found in combination with ſulphur, in the form of cinnabar. Mercury is a ſcarce metal. Moſt of the mercury in commerce is afforded by the mines of Idria in the Auſtrian dominions, Almaden in Spain, and Guancavelica in Peru. The native mercury requires little more than waſhing to ſeparate it from its matrix. Cinnabar in the native ſtate is frequently mixed with calcareous earth;

in

Decompoſition of cinnabar.

ı which caſe the mercury may be ſeparated by diſtilla- on, becauſe the calcareous earth combines with and tains the ſulphur. Pure cinnabar may be decom- oſed by the addition of about one third of its weight iron. In all caſes wherein pure mercury is re- uired, it muſt be diſtilled from cinnabar, or its ſul- hureous combination. For this purpoſe, the mercury ay be converted into ethiops, and diſtilled with twice s weight of quicklime or iron filings. Mercury in ommerce is judged to be pure when it is perfectly uid, and runs in neat globules, without any pellicle n its ſurface, or without ſoiling a funnel of clean hite paper, through which it may be poured by a ery ſmall aperture at bottom. If it leaves nothing ehind after evaporation, its purity may be ſtill more epended upon.

Purity of mercury.

Humid analyſis of cinnabar.

To analyſe native cinnabar, its ſtony matrix ſhould rſt be diſſolved in nitrous acid; and the cinnabar, eing diſengaged, ſhould be boiled in eight or ten mes its weight of aqua regia, compoſed of three arts nitrous, and one marine acid: the mercury may en be precipitated in the metallic form by the addi- on of zinc.

Uſes of mercury.

The uſes of mercury have already been mentioned ı the preſent chapter, and elſewhere. The amalga- ation of the noble metals, water-gilding, the making f vermilion, the ſilvering of looking-glaſſes, and the reparation of ſeveral powerful medicines, are the rincipal uſes to which this metal is applied.

CHAP. V.

CONCERNING LEAD.

LEAD.

Characters of lead.

Granulated,

Page 65.

LEAD is a white metal, of a conſiderably blue tinge, very ſoft and flexible, not very tenacious, and conſequently incapable of being drawn into fine wire, though it is eaſily extended into thin plates under the hammer. Its weight is very conſiderable, being rather greater than that of ſilver. Long before ignition, namely at about the 540th degree of Fahrenheit's thermometer, it melts; and then begins to be calcined, if reſpirable air be preſent. In a ſtrong heat it boils, and emits fumes; during which time, if expoſed to the air, its calcination proceeds with conſiderable rapidity. If melted lead be poured into a box previouſly rubbed with chalk to prevent its action on the wood, and be continually agitated, it will concrete into ſeparate grains, of conſiderable uſe in various mechanical operations, particularly that of weighing. Lead is brittle at the time of congelation. In this ſtate it may be broken to pieces with a hammer, and the cryſtallization of its internal parts will exhibit an arrangement in parallel lines.

Calcination.

Minium, or red lead.

This metal, during the progreſs of heat, firſt becomes converted into a duſky powder, which by a continuation of the heat becomes white, yellow, and afterwards of a bright red inclining to orange colour, called minium, or red lead. The proceſs requires conſiderable management with regard to the heat and

acceſs

ceſs of air, in the making of red lead. Many days are quired for this purpoſe. If the heat be too great or id, the lead becomes converted into a flaky ſub- nce, called litharge; and a ſtill greater heat con- rts it into a clear, tranſparent, yellow glaſs, which werfully diſſolves and corrodes metallic calces or rths; and on this account it uſually finds its way rough the crucibles in a ſhort time. It acts more ficultly on argillaceous than on ſiliceous earths; ence it is found that veſſels made of clay mixed th broken pottery are preferable to thoſe that are mpoſed of clay and ſand. The calx of lead is a incipal ingredient in moſt of the modern fine white ſſes. It is more particularly calculated to form the nſe glaſs uſed to correct the aberration ariſing from lour in thoſe teleſcopes which are known by the me of achromatic; becauſe it communicates the operty of ſeparating the coloured rays from each er in greater angles than obtain in alkaline glaſſes equal angles of mean refraction. The imperfection ich moſt conſiderably affects this kind of glaſs is, t its denſity is ſeldom uniform throughout. The egularities ſhew themſelves in the form of veins, ich greatly diſturb the regular refraction.

Litharge and glaſs of lead.

Achromatic teleſcope.

Lead is not much altered by expoſure to air or ter; though the brightneſs of its ſurface, when cut ſcraped, very ſoon goes off. It is probable that a n ſtratum of calx is formed on the ſurface, which fends the reſt of the metal from corroſion.

Action of air and water on lead;

Moſt of the acids attack lead. The vitriolic acid es not act upon it, unleſs it be concentrated and iling. Vitriolic acid air eſcapes during this proceſs,

— of vitriolic acid.

LEAD.

ceſs, and the acid is decompoſed. When the diſtillation is carried on to dryneſs, a ſaline white maſs remains, a ſmall portion of which is ſoluble in water, and is the vitriol of lead: it affords cryſtals. The reſidue of the white maſs is a calx of lead.

Combination of nitrous acid and lead.

Nitrous acid acts ſtrongly on lead, and converts it into a white calx if the acid be concentrated; but if it be more diluted, the calx is diſſolved, and forms a nitre of lead which is cryſtallizable, and does not afford a precipitate by cooling. It detonates on ignited coals. Lime and alkalis decompoſe the nitrous ſolution of lead. The vitriolic acid added to this ſolution combines with the metallic calx, and falls down. The marine acid in the ſame manner carries down the lead, and forms a combination called plumbum corneum, which is more ſoluble in water than the horn ſilver,

Plumbum corneum:

— marine acid:

Marine acid acts directly on lead by heat, which it calcines, and diſſolves part of its calx. The marine ſalt of lead is cryſtallizable.

— acetous acid.

The acetous acid diſſolves lead and its calces; though probably the acceſs of air may be neceſſary for the ſolution of the metal itſelf in this acid.

White lead, or ceruſe.

White lead, or ceruſe, is made by rolling leaden plates ſpirally up, ſo as to leave the ſpace of about an inch between each coil, and placing them vertically in earthen pots, at the bottom of which is ſome good vinegar. The pots are to be covered, and expoſed for a length of time to a gentle heat in a ſand bath, or by bedding them in dung. The vapour of the vinegar, aſſiſted by the tendency of the lead to combine with the pure part of the air which is preſent,

ſent, corrodes the lead, and converts the external portion into a white calx, which comes off in flakes when the lead is uncoiled. The plates are thus treated repeatedly until they are corroded through. Ceruſe is the only white ſubſtance uſed in oil paintings. It may be diſſolved without difficulty in the acetous acid, and affords a cryſtallizable ſalt, called ſugar of lead from its ſweet taſte. This, like all the preparations of lead, is a moſt deadly poiſon.

Sugar of lead.

Liver of ſulphur precipitates lead from its ſolutions, the ſulphur falling down in combination with the lead. Pure alkaline ſolutions diſſolve a ſmall portion of lead, and corrode a conſiderable quantity: the ſolution is ſaid to give a black colour to the hair.

Action of liver of ſulphur on lead: — of alkalis;

Oils diſſolve the calces of lead, and become thick and conſiſtent; in which ſtate they are uſed as the baſis of plaſters, cements for water works, paint, &c.

— oils.

In the dry way, lead alone is calcined and vitrefied. When fuſed with fixed alkaline ſalts, it is converted into a dark-coloured ſcoria, partly ſoluble in water. The neutral ſalts in general are not acted upon by lead. Nitre calcines this metal when heated with it, though ſcarcely any commotion or apparent flame is produced by its action. Sulphur readily diſſolves it in the dry way, and produces a brittle compound, of a deep grey colour and brilliant appearance, which is much leſs fuſible than lead itſelf; a property which is common to all the combinations of ſulphur with the more fuſible metals.

Habitudes in the dry way.

The

LEAD.

Habitudes with phoſphoric acid. The phoſphoric acid, expoſed to heat together with charcoal and lead, becomes converted into phoſphorus, which combines with the metal. This combination does not greatly differ from ordinary lead: it is malleable, and eaſily cut with a knife; but it loſes its brilliancy more ſpeedily than pure lead; and, when fuſed upon charcoal with the blow-pipe, the phoſphorus burns, and leaves the lead behind.

Decompoſition of ſal ammoniac: Lead decompoſes ſal ammoniac by the aſſiſtance of heat: its calces unite with the marine acid of that ſalt in the cold, and diſengage its volatile alkali. When volatile alkali is obtained by diſtilling ſal ammoniac with the calces of lead, the reſidue conſiſts of plumbum corneum.

— of common ſalt. Litharge fuſed with common ſalt decompoſes it; the lead unites with the marine acid, and forms a yellow compound, at preſent uſed in this country as a pigment, for which an excluſive privilege has been granted. (Page 118.) The alkali either floats at top, or is volatilized by the heat if ſtrongly urged. The ſame decompoſition takes place in the humid way, if common ſalt be macerated with litharge; and the ſolution will contain cauſtic alkali.

Combinations of lead with metals. Lead unites with moſt of the metals. Gold and ſilver are diſſolved by it in a ſlight red heat. Both theſe metals are ſaid to be rendered brittle by a ſmall admixture of lead, though lead itſelf is rendered more ductile by a ſmall quantity of them. Platina forms a brittle compound with lead; mercury amalgamates with it; but the lead is ſeparated from the mercury by agitation, in the form of an impalpable black powder, vital air being at the ſame time abſorbed. The preſence of vital air is indiſpenſably neceſſary in this proceſs. Copper and lead do not unite but with a ſtrong heat. If lead be heated ſo as to boil and ſmoke, it ſoon diſſolves pieces of copper thrown into it; the mixture when cold is brittle. The union of theſe two metals is remarkably ſlight; for upon expoſing the maſs to a heat no greater than hat in which lead melts, the lead almoſt entirely runs off by itſelf. This proceſs, which is peculiar o lead with copper, is called eliquation. The coarſer orts of lead, which owe their brittleneſs and granulated texture to an admixture of copper, throw it up to the ſurface on being melted by a ſmall heat. Iron does not unite with lead, as long as both ſubſtances retain their metallic form. Tin unites very eaſily with this metal, and forms a compound which is much more fuſible than lead by itſelf, and is for that reaſon uſed as a ſolder for lead. Two parts of lead and one of tin form an alloy more fuſible than either metal alone: this is the ſolder of the plumbers. Biſmuth combines readily with lead, and affords a metal of a fine cloſe grain, but very brittle. A mixture of eight parts biſmuth, five lead, and three tin, will melt in a heat which is not ſufficient to cauſe water to boil. Regulus of antimony forms a brittle alloy with lead. Wolfram unites with it into a ſpongy ductile compound, which ſplits into leaves when hammered. Nickel, cobalt, mangane ſe, and zinc, do not unite with lead by fuſion.

Combinations of lead and copper; decompoſed by eliquation, or by low heat.

Plumbers ſolder.

Fuſible mixture.

T All

LEAD.

Revival of the calces of lead.

All the calces of lead are very eaſily revived. Minium, when expoſed to a ſtrong heat, gives out part of the vital air it abſorbed during its calcination; but, like the other calces of this metal, it requires the addition of ſome combuſtible ſubſtance for its complete revival. A familiar inſtance of this revival is ſeen by expoſing the common wafers to the flame of a candle. Theſe wafers are coloured with minium, which is revived by the heat and inflammable ſubſtance of the wafer, ſo that it falls down in metallic globules.

Native lead and its ores.

Analyſis of calciform ores.

Lead is found native, though ſeldom; and alſo in the form of a calx, called native ceruſe, or lead ochre, or lead ſpar of various colours, red, brown, yellow, green, blueiſh, and black. Theſe ores, when freed as much as poſſible from earthy matter, may be diſſolved in diluted nitrous acid. Calx of iron is uſually thrown down from the ſolution by boiling. If the lead be then precipitated by the mild mineral alkali, and weighed, 132 grains of the dry precipitate will correſpond with 100 grains of lead in the metallic ſtate. If the precipitate be ſuſpected to contain copper, it may be ſeparated by digeſting in volatile alkali. If it be ſuppoſed to contain ſilver and copper, the precipitate may again be diſſolved in nitrous acid, and ſeparated by the addition of marine acid; which combining with the metal, produces luna cornea, and plumbum corneum; the latter of which, being ſoluble in 30 times its weight of boiling water, may be waſhed off, while the ſilver remains undiſſolved; or the ſilver, if alone in the precipitate, may be

taken

Native ſalts of lead.

Humid analyſis of phoſphoric lead ore.

aken up by volatile alkali, which will leave the alx of lead of the ſame value with regard to eight as the foregoing. Lead is alſo found mineralized by the vitriolic and the phoſphoric acids: is laſt is of a greeniſh colour, ariſing from a ixture of iron. The vitriol of lead is ſoluble in bout 18 times its weight of water. One hundred nd forty-three grains of the dried ſalt repreſent 100 rains of lead. The phoſphoric lead ore may be iſſolved in nitrous acid by means of heat, except a w particles of iron, which remain at the bottom. y the addition of vitriolic acid the lead is thrown own in the form of white flakes of vitriol; which, hen waſhed and dried, diſcover the quantity of lead ey contain, by the ſame allowance of 143 grains of e ſalt to 100 grains of metallic lead. The remaing ſolution being evaporated to dryneſs, affords phoſoric acid.

Sulphureous ore of lead; or galena.

Lead is abundantly found in combination with lphur, in the form of heavy, ſhining, black, or ueiſh lead-coloured cubical maſſes, whoſe corners e uſually truncated; its texture is laminated, and s hardneſs variable. This is called galena, or potters ad ore. Moſt lead ores contain more or leſs of ver. When antimony enters into its compoſition, e texture is radiated or filamentous. There are ſo lead pyrites, which contain a conſiderable prortion of iron and ſulphur; and red lead ſpar, hich conſiſts of lead mineralized by ſulphur and ſenic: this is very ſcarce.

Analyſis of ſulphurated lead.

If ſulphurated lead be boiled in nitrous or marine id of a moderate ſtrength, the ſulphur may be obtained pure, and collected on a filter. When iron or ſtony particles are contained among the undiſſolved part, the ſulphur may be ſeparated by digeſtion in a ſolution of cauſtic fixed alkali, which converts it into liver of ſulphur, and leaves the other inſoluble matters behind. If the firſt ſolution be made with nitrous acid, it may contain ſilver and lead, which, after precipitation by mild mineral alkali, may be ſeparated by the volatile alkali, as mentioned in the humid analyſis of the calciform ores: when the marine acid is uſed for the ſolution of the ore, a large quantity of plumbum corneum ſeparates, for want of a ſufficient quantity of water to diſſolve it. This requiſite quantity of water muſt be added to diſſolve the ſalt before the precipitate is made by the fixed alkali.

Revival of lead by the blow-pipe.

All the ores of lead, except the phoſphoric, are reducible to the metallic ſtate by diſſipating their volatile contents by the blow-pipe on a piece of charcoal. In the large way, they are revived by fuſion with charcoal.

Uſes of lead.

The ores of this metal are abundantly found in the mine counties of England, and in various other parts of the globe. Its uſes are numerous, and ſcarcely need be mentioned. Its calces have been already mentioned as of great uſe as a pigment, and in the manufacture of glaſs. Lead is caſt into thin ſheets for covering buildings, making water-pipes, and various other uſes; and this is rolled between two cylinders of iron, to give it the requiſite uniformity and thinneſs. Lead is thought, and with ſome reaſon, to be not perfectly innocent even for water-pipes,

LEAD.

pipes, and much leſs ſo for any other kind of veſſels. The workmen in any of the preparations of lead are generally ſubject to a peculiar colic, and paralytic diſorders; which moſt probably ariſe from the in-ernal uſe of the metal: for it is a fact that theſe workmen are not ſufficiently cautious in waſhing heir hands, or removing ſuch particles of lead, or ts preparations, as may caſually intermix with their ood.

CHAP. VI.

CONCERNING COPPER.

COPPER.

Characters of copper.

COPPER is a metal of a peculiar reddiſh brown colour; hard, ſonorous, very malleable, and ductile; of conſiderable tenacity, and of a moderate ſpecific gravity. At a degree of heat far below ignition the ſurface of a piece of poliſhed copper becomes covered with various ranges of priſmatic colours, the red of each order being neareſt the end which has been moſt heated; an effect which muſt doubtleſs be attributed to calcination, the ſtratum of calx being thickeſt where the heat is greateſt, and growing gradually thinner and thinner towards the colder part. A greater degree of heat calcines it more rapidly, ſo that it contracts thin powdery ſcales on its ſurface, which may be eaſily rubbed off; the flame of the fuel becoming at the ſame time of a beautiful blueiſh green colour. In a ſtrong white heat, nearly the ſame as is neceſſary to melt gold or ſilver, it melts, and exhibits a blueiſh green flame; by a violent heat it boils, and is volatilized partly in the metallic ſtate.

See Newton's Optics.

Corroſion of copper:

Copper ruſts in the air; but the corroded part is very thin, and preſerves the metal beneath from further corroſion.

— and ſolution in vitriolic acid.

The vitriolic acid, when concentrated and boiling, diſſolves copper. A brown thick fluid, containing calx of copper, and a portion of the calx combined with vitriolic acid, is found at the bottom of the ſolvent. If water be added to this, it forms a blue ſolution of copper, which by evaporation affords blue cryſtals, that require about four times their weight of water to diſſolve them. This ſolution lets fall a calx of copper of a green colour by long expoſure to the air.

Vitriolic combinations and precipitates.

The ſolutions of copper in vitriolic acid are ſlightly cauſtic. Magneſia, lime, and the fixed alkalis, precipitate the metal from them in the form of calx. Volatile alkali precipitates all the ſolutions of copper; but rediſſolves the calx, and produces a deep blue colour. Copper is precipitable from moſt of its ſolutions in the metallic ſtate by the addition of iron: a clean plate of iron-ſoon becomes covered with a coating of copper when immerſed in the ſolution: hence the volatile alkali, and the application of iron, are conſidered as the teſts of the preſence of copper. There are certain mineral waters in Hungary, Sweden, Ireland, and in various parts of England, which contain vitriol of copper, and from which it is precipitated by the addition of pieces of old iron.

Nitrous combination of copper.

Nitrous acid diſſolves copper with great rapidity, and diſengages a large quantity of nitrous gas. Part of the metal falls down in the form of a calx; and the filtrated or decanted ſolution, which is of a much deeper blue colour than the vitriolic ſolution, affords cryſtals by ſlow evaporation. This ſalt is deliqueſcent, very ſoluble in water, but moſt plentifully when the fluid is heated. Its ſolution, expoſed to the air in ſhallow veſſels, depoſits a calx of a green colour. Lime precipitates the metal of a pale blue; fixed

COPPER.

alkalis, of a blueiſh white. Volatile alkali throws down blueiſh flocks, which are quickly rediſſolved, and produce a lively blue colour in the fluid.

Solution of copper in marine acid:

Marine acid does not readily diſſolve copper, unleſs it be concentrated and boiling. The ſolution is of a deep brown colour; but, on ſtanding for ſome time, it depoſits a ſediment, and becomes green. By careful evaporation it yields cryſtals; or, when inſpiſſated, it affords a greeniſh maſs, which deliqueſces in the air, is readily diſſolved in water, gives a green tincture to ardent ſpirit, melts in a gentle heat, takes fire from a candle, and burns with a blue flame. The marine acid diſſolves the calces of copper more readily than the metal itſelf; but the ſolution does not differ from the foregoing.

— in vegetable acids.

Vegetable acids diſſolve copper ſlowly; but in conderable quantity, if reſpirable air be preſent. In this, as in a number of other metallic ſolutions, it appears that the diſpoſition of the air to calcine the metal is greatly aſſiſted by the elective attraction of the acid for the metallic calx. Vinegar does not diſſolve copper when boiling, becauſe the ſteam prevents the aceeſs of the air; but the ſame acid ſtanding for a day in a copper veſſel, will contract a dangerous metallic impregnation. This circumſtance accounts for the unhappy conſequences in ſome inſtances attending the uſe of copper veſſels, which in other caſes have produced no noxious effects. Confectioners boil pickles, and even lemon juice, in clean copper veſſels, without obſerving any bad taſte or noxious conſequence to follow. We cannot however avoid heartily concurring in the general opinion which now prevails,

Effect of the preſence of air.

vails, in the rejection of copper veſſels for culinary purpoſes.

Fabrication of verdigris.

Verdigris is a calx of copper prepared in large quantities near Montpellier in France, by ſtratifying copper plates with the huſks of grapes which remain after the juice has been preſſed out. Theſe ſoon become acid, and corrode the copper. A ſolution of this calx in diſtilled vinegar affords permanent cryſtals, improperly called diſtilled verdigris.

Solution of copper in fixed alkalis:

Fixed alkalis have ſome action on copper, with which they form a light blue ſolution. This, as well as the volatile alkaline ſolution, appears to ſucceed better in the cold than by the aſſiſtance of heat, for the ſame reaſon as the cold acetous acid acts upon copper; namely, the facility with which the metal is calcined by the acceſs of air.

— in volatile alkali.

Volatile alkali diſſolves copper with much greater rapidity than fixed alkalis, whether it be in the metallic or calciform ſtate; and forms a beautiful blue ſolution. This fluid has long attracted the notice of chemiſts, on account of its becoming colourleſs in cloſed veſſels; and recovering its colour, which gradually extends from the ſurface downwards, when the veſſel is opened. This effect is explained by the ſuppoſition, that the perfect ſolution of calx of copper in volatile alkali is colourleſs when the alkali is in exceſs; but that it is blue when it abounds with calx of copper: and accordingly it is found that the loſs of colour on keeping the veſſel cloſed for ſome time, and its re-appearance on opening the veſſel, does not ſucceed with old ſolutions, which are permanently blue. The air calcines

COPPER.

Habitudes of copper with volatile alkali:

cines more perfectly a portion of the ſuſpended copper, which gives a blue colour to the fluid until it has more intimately combined with the alkali. If this combination be made in the cloſed veſſel, the colour diſappears; if it be made in the open veſſel, the calcination of another portion goes on, and continues until the alkali is ſaturated, and can combine with no more: ſo that the laſt portion of perfect calx, which cauſes the blue colour, does not ſeem to have entered into ſo intimate a combination, for want of an exceſs of alkali. The alkali does not take up any conſiderable quantity when applied to copper filings; but it diſſolves much more of the calces of copper. The ſolution does not very readily afford cryſtals.

— with oils, earths, alkalis, and neutral ſalts.

Oils do not ſeem to act upon copper until they become rancid; in which caſe their diſengaged acid corrodes the copper, and the oil aſſumes a blueiſh green colour. Verdigris is ſoluble in ardent ſpirit. Copper in the metallic ſtate does not unite with earths or alkalis in the dry way: its calces enter into the compoſition of glaſs. In general, it does not act on the neutral ſalts by fuſion. Nitre detonates with it but difficultly. Filings of copper are thrown upon red-hot nitre; and the reſidue is a browniſh grey calx, mixed, and partly combined, with vegetable alkali. If this be waſhed with water, the remaining calx may be fuſed, without other addition, into a deep opake brown glaſs, uſed by enamellers.

— ſal ammoniac.

Sal ammoniac is decompoſed by copper filings. The produce which comes over conſiſts of cauſtic volatile alkali, rendered blue by a ſmall portion of copper, together with alkaline air, inflammable air, and phlogiſticated air: the reſidue conſiſts partly of marine ſalt of copper and calx. In this experiment we find that the copper detains the acid; while the volatile alkali, being ſet at liberty, comes over into the receiver. The inflammable and phlogiſticated air cannot ſo clearly be accounted for, as they may ariſe either from part of the alkali being decompoſed into its firſt principles; or the inflammable air may be ſupplied during the ſolution of the copper; in which caſe it will proceed from the phlogiſton of that metal, according to the hypotheſis of Stahl; or from a decompoſition of part of the water of cryſtallization of the ſal ammoniac; the pure air of which will be communicated to the copper, in order to calcine and render it ſoluble in the marine acid, while its inflammable air comes over in the elaſtic ſtate.

Habitudes of copper with ſal ammoniac:

A ſolution of alum boiled in a copper veſſel depoſits ſome earth; and the fluid exhibits ſigns of the preſence of copper by the teſt of volatile alkali. This does not ſeem to be a perfect decompoſition of the alum; but appears to be effected by virtue of the acid, which that ſalt contains in exceſs. The neutral ſalt or alum, ſaturated with its own baſis, falls down, becauſe leſs ſoluble; while the exceſs of acid, forming vitriol of copper, exhibits the blue tinge when volatile alkali is added.

— with alum.

Copper unites very readily with ſulphur. If copper filings be mixed with flowers of ſulphur and a little water, the combination takes place; but it is much more

— with ſulphur.

more readily effected in the dry way. This cannot be done by direct fuſion, becauſe the ſulphur is burned at a much leſs heat than is required to fuſe the copper. It may be prepared by mixing equal parts of ſulphur and copper filings together, and expoſing them to heat, gradually raiſed to ignition: or plates of copper may be ſtratified in a crucible with ſulphur, and gradually heated as before. This compound is a blackiſh grey maſs; and is uſed by dyers and callico printers: it is diſtinguiſhed by the name of æs veneris. Liver of ſulphur diſſolves copper both in the humid and dry way.

Combination of copper with ſulphur:

— with phoſphorus.

Phoſphorus unites with the calx of copper: or if the phoſphoric glaſs be expoſed to heat in a crucible, together with its weight of copper filings, and about $\frac{1}{4}$ of its weight of charcoal, the phoſphorus which is formed combines with the copper into a kind of pyrites, which changes by expoſure to air. It loſes its metallic ſtate, and aſſumes a black colour.

— with metallic ſubſtances.

The combinations of copper with the metals before treated of have been already mentioned. It unites imperfectly with iron in the way of fuſion. Tin very readily combines with copper at a temperature much lower than is neceſſary to fuſe copper alone. On this is grounded the method of tinning copper veſſels. For this purpoſe, they are firſt ſcraped, or ſcoured; after which they are rubbed with ſal ammoniac. They are then heated, and beſprinkled with powdered reſin, which defends the clean ſurface of the copper from acquiring the ſlight film of calx, which would prevent the adheſion of the tin to its ſurface. The melted tin is then poured in, and ſpread about.

An extremely ſmall quantity adheres to the copper; which may with great juſtice be ſuppoſed inſufficient to prevent the noxious effects of the copper as perfectly as might be wiſhed.

Bronzes and bell-metal.

When tin is melted with copper, it compoſes the compound called bronze. In this metal the ſpecific gravity is always greater than would be deduced by computation from the quantities and ſpecific gravities of its component parts. The uſes of this hard, ſonorous, and durable compoſition, in the fabrication of cannon, bells, ſtatues, and other articles, are well known. Bronzes and bell-metals are not uſually made of copper and tin only, but have other admixtures, conſiſting of lead, zinc, or arſenic, according to the motives of profit, or other inducements of the artiſt. But the attention of the philoſopher is more particularly directed to the mixture of copper and tin, on account of its being the ſubſtance of which the ſpeculums of reflecting teleſcopes are made. The metal required for this purpoſe ought to be capable of an exquiſite poliſh, hard enough to receive and retain a figure accurately ſuited to the regular reflection of light, and not ſubject to become tarniſhed by the action of the atmoſphere. Many excellent teleſcopes have been made with compoſitions of pure copper, alloyed with ſomewhat leſs than half its weight of tin. But it appears to be very well aſcertained, from the obſervations of the Aſtronomer Royal, that the ſpeculums of Mr. Edwards, whoſe compoſition was the reſult of numerous trials, are much ſuperior to any which have yet been made; and are even equal in light to acromatic

Metal for ſpeculums.

COPPER.

Edwards's method of making ſpeculums.

matic teleſcopes of the ſame aperture, without altering the colours of objects. He firſt melts 32 parts of copper as fluid as poſſible, with one part of braſs and one of ſilver, together with the black flux; at the ſame time that fifteen parts of tin are melted in a ſeparate crucible by itſelf. Theſe being taken from the fire, he pours the tin to the copper; immediately ſtirs the whole together with a wooden ſpatula, and pours it out haſtily into a large quantity of cold water, which cools and granulates the compoſition. If the tin were fuſed together with the copper, or if they were to remain for any length of time in the extreme heat which is neceſſary to fuſe this laſt metal, a part of the tin would be calcined, and the metal would abound more or leſs with ſmall microſcopic pores. If one of the pieces of the cold metal be broken, it will appear of a moſt beautiful bright colour, reſembling quickſilver. Mr. Edwards affirms, that different kinds of copper require different doſes of tin to produce the moſt perfect whiteneſs. If the doſe of tin be too ſmall, which is the fault moſt eaſily remedied, the compoſition will be yellowiſh; if it be too great, the compoſition will be of a grey blue colour, and dull appearance. He therefore finds by trial the quantity of tin neceſſary to be added in the ſecond fuſion to render the metal the moſt perfect. A much leſs degree of heat is then required to melt the compound. In the ſecond melting he adds one part of arſenic, and immediately ſtirs the mixture; which he pours into the mould as ſoon as the fumes of the arſenic have ceaſed to riſe. He caſts the ſpeculum in ſand, with the face downwards; takes it out while red-hot, and places it in hot wood aſhes to cool; without which precaution it would break in cooling *.

Metallic mixtures.

Copper unites with biſmuth, and forms a reddiſh white alloy. With arſenic it forms a white brittle compound, called tombac. With zinc it forms the compound called braſs, and diſtinguiſhed by various other names, according to the proportions of the two ingredients. It is not eaſy to unite theſe two metals in conſiderable proportions by fuſion, becauſe the zinc is burned or volatilized at a heat inferior to that which is required to melt copper; but they unite very well in the way of cementation. In the braſs works, copper is granulated by pouring it through a plate of iron, perforated with ſmall holes and luted with clay, into a quantity of water about four feet deep, and continually renewed: to prevent the dangerous exploſions of this metal, it is neceſſary to pour but a ſmall quantity at a time. There are various methods of combining this granulated copper, or other ſmall pieces of copper, with the vapour of zinc. Calamine, which is an ore of zinc, is pounded, and

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* As the conſtruction of teleſcopes is foreign to the immediate purpoſe of this work, it has not been thought neceſſary to mention the ſeveral precautions of Mr. Edwards in this buſineſs: but the curious operator, who may wiſh to undertake the conſtruction of a reflecting teleſcope (the better kinds of which are not only difficult to be procured, but of conſiderable price), may have recourſe to Edwards's Treatiſe, annexed to the Nautical Almanack for 1787; where he will find ample inſtructions for that purpoſe.

mixed

The fabrication of braſs.

mixed with the divided copper, together with a portion of charcoal. Theſe being expoſed to the heat of a wind furnace, the zinc becomes revived, riſes in vapour, and combines with the copper, which it converts into braſs. The heat muſt be continued for a greater or leſs number of hours, according to the thickneſs of the pieces of copper, and other circumſtances; and at the end of the proceſs the heat, being ſuddenly raiſed, cauſes the braſs to melt, and occupy the lower part of the crucible. The moſt ſcientific method of making braſs ſeems to be that mentioned by Cramer*. The powdered calamine, being mixed with an equal quantity of charcoal, and a portion of clay, is to be rammed into a melting veſſel; and a quantity of copper, amounting to two thirds of the weight of the calamine, muſt be placed on the top, and covered with charcoal. By this management the volatile zinc aſcends, and converts the copper into braſs, which flows upon the rammed clay: conſequently, if the calamine contain lead, or any other metal, it will not enter into the braſs, the zinc alone being raiſed by the heat.

Leaf braſs, or Dutch gold.

A fine kind of braſs, which is ſuppoſed to be made by cementation of copper plates with calamine, is hammered out into leaves in Germany; and is ſold very cheap in this country, under the name of Dutch gold. It is, as I find, about five times as thick as gold leaf; that is to ſay, it is about one ſixty-thouſandth of an inch thick.

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* Art of Aſſaying Metals. London, 1764. Page 377.

If

Metallic mixtures.

If braſs be kept in a ſtate of ignition, with contact of air, the zinc burns, and the copper remains. Whether the zinc would quit the braſs without combuſtion, is not known; though there is little doubt but it might be driven off in cloſe veſſels.

The quantity of zinc in good braſs is about one third of its weight.

Copper unites readily with regulus of antimony; and affords a compound of a beautiful violet colour. It does not readily unite with manganeſe. With wolfram it forms a dark brown ſpongy alloy, which is ſomewhat ductile.

Native copper, and its ores.

Copper is either found native, moſtly in an impure ſtate; or in the form of a calx, of a red, green, or blue colour. The native ſolutions of copper frequently impregnate calcareous earths, in which they depoſit the metal. The turquoiſe ſtone is the tooth of an animal, penetrated with the blue calx of copper. Many ores of copper contain ſulphur. Among theſe, the vitreous copper ore is of a red, brown, blue, or violet colour; ſometimes cryſtallized, but uſually ſoft enough to be cut with a knife. Some of the pyrites contain a conſiderable proportion of copper, together with iron, ſulphur, and clay. The grey copper ore is a ſulphureous combination, containing arſenic: it is of a white, grey, or brown colour, heavy, and difficult of fuſion. Blendoſe copper ore is of a brown colour, hard, ſolid, compact, and granulated: it contains the metal, with ſulphur, arſenic, zinc, and iron. Some ſlates, and one ſpecies of coal, afford copper; and

COPPER.

ſeveral waters contain this metal, diſſolved in vitriolic or marine acid.

Aſſay of native copper:

Native copper may be aſſayed in the humid way by ſolution in nitrous acid. If it contain gold, this metal falls untouched to the bottom, in the form of a black powder; if ſilver, it is ſoon precipitated by more copper; if iron, by boiling the ſolution for ſome time, it is gradually calcined, and falls to the bottom.

— of calciform ores:

The calciform copper ores are ſoluble in acids, and may be precipitated either by iron, which affords the copper in the metallic ſtate; or by mild alkali, which throws down 194 grains of precipitate for every 100 grains of copper.

— of ſulphureous ores:

Sulphureous copper ores may be powdered, and gently boiled to dryneſs in five times their weight of concentrated vitriolic acid. The whole, or moſt part of the ſulphur, flies off by this heat. The vitriolic ſalt of copper requires at leaſt four times its weight of water to diſſolve it. A ſufficient quantity being therefore added, and a poliſhed iron plate boiled in the ſolution, the copper will be precipitated. If iron be found to be mixed with the precipitate, it muſt be again diſſolved, to obtain a richer ſolution. This will depoſit pure copper, if the operation be conducted as before. If it contain other metals, they may be eaſily ſeparated by ſolution in nitrous acid.

— in the dry way.

In the dry way, the ſulphureous ores of copper muſt be firſt pulverized, and ſeparated as much as poſſible from the earthy and ſtony particles; then roaſted, to ſeparate the ſulphur and arſenic; and, laſtly, melted with an equal weight of M. Tillet's flux, which conſiſts of two parts of pounded glaſs, one calcined borax, and $\frac{1}{8}$ of charcoal. More borax may be added if the ore be poor. Alkaline fluxes are hurtful in the fuſion of copper ores, becauſe the ſalt combines with the ſulphur, and forms hepar, which diſſolves part of the copper.

Treatment of copper ores in the large way.

In the large way, copper is roaſted in a cloſe furnace, by a ſlow fire, to ſcorify the mixtures of iron, and other ſubſtances. By repeated fuſions with ſulphur and charcoal, the ſcorified metal riſes to the top, and is ſcummed off. The copper in the great Hungarian mines is ſaid to undergo fuſion fourteen times before it is fit for ſale. The roaſted ore in the iſle of Angleſey is deprived of its vitriolic ſalt by waſhing; and the copper is precipitated by means of old iron immerſed in the water. This precipitated copper is, however, but a ſmall proportion of the whole produce.

Countries where copper is found.

Copper is found in various parts of the world; in Spain, France, England, Norway, Hungary, Sweden, and elſewhere. The Japan copper is ſaid to be purer, and has a greater ſpecific gravity, than any other copper. The wire-drawers, who require copper of extraordinary ductility, uſe the Swediſh copper. The copper mines in England are exceedingly numerous and productive. Paris mountain, on the iſle of Angleſey, contains a bed of ore forty feet in thickneſs; and is ſaid to produce upwards of four thouſand tons of copper annually.

COPPER.

Copper applied to various uſes.

The uſes of this metal are too numerous to be diſtinctly ſpecified. It has for ſome years paſt been applied with great ſucceſs and advantage, for ſheathing the bottoms of ſhips; and ſeveral builders have lately endeavoured to introduce it as a covering for houſes. It is the lighteſt of all coverings; but whether it be more durable than ſlate, which is nearly as light, has not yet been aſcertained by experience.

CHAP. VII.

CONCERNING IRON.

IRON.

Characters of iron.

IRON is a metal of a blueiſh white colour, of conſiderable hardneſs and elaſticity; very malleable, exceedingly tenacious and ductile, and of a moderate ſpecific gravity among metallic ſubſtances. It is much diſpoſed to ruſt by the acceſs of air, or the action of water, in the common temperature of the atmoſphere. The appearance of priſmatic colours on its poliſhed ſurface takes place long before ignition; and at ſo low a temperature, that the ſlighteſt coating of greaſe is ſufficient to prevent their appearance, by defending it from the contact of air. It may be ignited, or at leaſt rendered ſufficiently hot to ſet fire to brimſtone, by a quick ſucceſſion of blows with a hammer. When ſtruck with a flint, or other hard ſtone, it emits decrepitating ignited particles, ſuch as can be obtained from no other metal by the ſame means. Theſe particles are ſeldom larger than the two hundredth part of an inch in diameter; and, when examined by a magnifier, are found to be hollow, brittle, and of a greyiſh colour, reſembling the ſcales of burned iron. This metal is eaſily calcined by fire. A piece of iron wire, immerſed in a jar of vital air, being ignited at one end, will be entirely conſumed by the ſucceſſive combuſtion of its parts. It requires a moſt intenſe heat to fuſe it; on which account it can only be brought into the ſhape of tools and utenſils

Characters of iron.

fils by hammering. This high degree of infuſibility would deprive it of the moſt valuable property of metals, namely, the uniting of ſmaller maſſes into one, if it did not poſſeſs another ſingular and advantageous property, which is found in no other metal except platina; namely, that of welding. In a white heat iron appears as if covered with a kind of varniſh; and in this ſtate, if two pieces be applied together, they will adhere, and may be perfectly united by forging. Iron is thought to be the only ſubſtance in nature which has the property of becoming magnetical. It is highly probable, from the great abundance of this metal, that all ſubſtances which exhibit magnetiſm do contain iron; but it muſt be confeſſed that there remain many experiments to be made among the earths and powders which exhibit magnetical properties, before this negative propoſition, which confines magnetiſm to iron, can be admitted as proved.

Calcination of iron by water.

When iron is expoſed to the action of pure water, it acquires weight by gradual calcination, and inflammable air eſcapes: this is a very ſlow operation. But if the ſteam of water be made to paſs through a red-hot gun-barrel, or through an ignited copper or glaſs tube containing iron wire, the iron becomes converted into a calx; while inflammable air paſſes out at the other end of the barrel. This capital experiment* may be accounted for according to the ancient and modern theories. In the ancient theory, it is ſuppoſed that the water has combined with the iron, and diſengaged its phlogiſton in the form

Ancient theory.

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* Of M. Lavoiſier.

form of inflammable air; and conſequently that, when this calx is again revived by heating a portion of it in inflammable air with a burning glaſs, and water appears, at the ſame time that part of the inflammable air is abſorbed, the iron has imbibed phlogiſton, and given out its water. Clear as this explanation appears to be, the ſolution afforded by the modern theory is not leſs perſpicuous. The maintainers of this theory reaſon as follows: Iron has not been ſhewn to be a compound ſubſtance; let us therefore conſider it as a ſimple ſubſtance, until we poſſeſs experiments which ſhew the contrary. Water has been ſhewn to be a compound ſubſtance, by the experiment of its production, by burning dephlogiſticated and inflammable air together. We may fairly therefore affirm, that the inflammable air came from the water, in which we know it to exiſt; and that the vital air of the water, the peculiar inſtrument of calcination, has combined with the iron. On the other hand, when the iron is revived in inflammable air, the water which appears is the very product of combination which was decompoſed in the former inſtance. For the vital air quits the iron to unite in the fluid ſtate with the inflammable air; and the iron, being ſet at liberty, recovers its original ſtate; that is to ſay, it is revived.

Calcination of iron by water.

Modern theory.

See page 95.

Page 93. 131.

That the iron, in the one inſtance, attracts vital air from the water, and diſengages inflammable air; and, in the other inſtance, exhibits a leſs affinity with that ſubſtance, ſo as to reſtore it to its former combination; is a difficulty which, in the preſent ſtate of our information, can only be accounted for by ſuppoſing,

Difficulty.

Calcination of iron by water.

poſing, that the temperature in the furnace differs from that produced by the burning glaſs; and that theſe affinities, like moſt others in chemiſtry, are not the ſame at all temperatures. This difficulty affects both theories alike; for it is not eaſier to account for the contrary tranſitions of water and phlogiſton, which mutually expel each other in the old theory, than for the tranſitions of dephlogiſticated and inflammable air in the new theory.

Theory.

The philoſophers who reject phlogiſton inſiſt, moreover, that the weight of the inflammable air produced, being deducted from the weight of the water made uſe of, leaves a quantity equal to the increaſe the iron gains by calcination; and that by burning the whole inflammable air produced, with a quantity of vital air equal in weight to the gain of the iron, a new quantity of water is recompoſed, which is equal likewiſe to that made uſe of. Hence they urge, that it is infinitely more probable that the inflammable air came from the water than from the iron. The latter fact, of the recompoſition, is in their favour; but the former is not. For whatever the inflammable air comes from, the firſt equation will be true; that is to ſay, if the iron give out phlogiſton, and receive water, its acceſſion of weight will be equal to the difference between the water it has received, and the phlogiſton it has loſt; but the reproduction of the water loſt will ſhew that the inflammable air really correſponds with the quantity required to form* ſo much water, if we admit the accuracy of the experiments.

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* It may be urged that the two airs contain much water; and for that, as well as other reaſons, their abſolute quantities cannot

Solution of iron in the vitriolic acid.

The concentrated vitriolic acid ſcarcely acts on iron, unleſs it be boiling. When the acid is diſtilled to dryneſs from this metal, the retort is found to contain ſublimed flowers of ſulphur, and a white vitriolic maſs, partly ſoluble in water: the product which comes over is volatile vitriolic acid, and vitriolic acid air. If the vitriolic acid be diluted with two or three parts of water, it diſſolves iron readily, without the aſſiſtance of any other heat than is produced by the act of combination. During this ſolution, inflammable air eſcapes in large quantities. If heat be applied, the acid proceeds to diſſolve more iron, and depoſits a white ſaline maſs, or pale vitriol of iron.

Martial vitriol.

The combination of vitriolic acid and iron, called martial vitriol, is much more ſoluble in hot than cold water; and therefore cryſtallizes by cooling, as well as by evaporation. The cryſtals are effloreſcent, and

cannot be aſcertained. But it is not required to aſcertain their abſolute quantities: for it is enough if the two airs in this recompoſition be exactly in the ſame ſtate as in the original experiment, by which the component parts of water were determined. If a certain portion of water be neceſſary to inflammable air in the elaſtic ſtate, it muſt of courſe take it from the ſteam n the gun-barrel at the inſtant of its extrication, and not afterwards from the water of the receivers: this requires to be confirmed by an experiment over mercury. How far Dr. Prieſtey's experiments (Phil. Tranſ. lxxviii. and lxxix.) may affect he poſition, that water is a compound ſubſtance, cannot be clearly aſcertained until it is ſhewn that the acid produced in burning he two airs does not ariſe from impurity in one or both of hem. See page 95.

5 fall

IRON. Martial vitriol.

fall into a white powder by expoſure to a dry air, the iron becoming more calcined than before. A ſolution of martial vitriol, expoſed to the air, imbibes its vital part; and a portion of the iron, becoming too much calcined to adhere to the acid, falls to the bottom in the form of ochre. The ſolution, as well as the cryſtals it affords by evaporation, are thus rendered paler than before.

Page 140,

Martial vitriol is not made in the direct way, becauſe it can be obtained at leſs charge from the decompoſition of martial pyrites.

Theory of the effects of vitriolic acid upon iron; according to the doctrine of phlogiſton.

The different appearances which accompany the ſolutions of iron in the vitriolic acid, may be accounted for according to the principles either of the ancient or modern theories. In the ancient theory, iron being ſuppoſed to contain phlogiſton, or the principle of inflammability, is calcined in both caſes; that is to ſay, it gives out phlogiſton *. With the concentrated acid the ſolution does not take place; becauſe the capacity of the mixture for heat, and conſequently its abſolute quantity of heat, is too ſmall to ſupply what the increaſed capacity of the vitriolic acid air would require, and conſequently the iron is not decompoſed, But when heat is applied, the phlogiſton of the iron, uniting with the baſis of part of the acid, forms ſulphur; which, together with another portion of the acid, riſes in the form of vitriolic acid air; at the ſame time that the vital air of the decompoſed acid unites with the calx of iron, which becomes ſoluble

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* Kirwan, in Philoſ. Tranſact. vol. lxxii; and Eſſay on Phlogiſton, London, 1789, page 62, or page 28 of the old edition.

in the acid that remains: but when much water is preſent, as in the diluted acid, the heat is ſupplied from the great capacity of the water; the phlogiſton of the iron aſſumes the elaſtic form; and inflammable air flies off, while the acid unites with the calx of iron, and forms vitriol. The decompoſition of the acid in the former, and not in the latter caſe, is accounted for from its ſtrong attraction to the water. A conſiderable heat, applied with the diluted acid, calcines the iron more perfectly; which then either enters into the compoſition of pale vitriol, containing a larger proportion of acid, or falls down in the form of calx. The acceſs of air does the ſame thing more gradually.

Theory:

In the antiphlogiſtic theory, iron is aſſumed to be a ſimple ſubſtance; vitriolic acid is ſaid to be compoſed of vital air and ſulphur; and water is admitted to be decompoſable. When iron therefore is applied to concentrated vitriolic acid, the principles retain their order of combination at a common temperature; but as ſoon as the temperature is raiſed, the iron becomes calcined, by attracting vital air from part of the acid, whoſe ſulphur is therefore ſet at liberty, and flies off with another portion of the acid, in the form of vitriolic air; while the remaining acid combines with part of the calx. But when the acid is more diluted, the water itſelf is decompoſed; its inflammable air is diſengaged; its vital air unites with and calcines the iron; and the vitriolic acid diſſolves the calx.

— according to the antiphlogiſtic doctrine.

The neceſſity of heat being applied to the concentrated ſolution in the one caſe rather than the other, may be referred to the capacities of the bodies, before and

Theory of the action of vitriolic acid on iron.

and after the change, in either theory. But it muſt be confeſſed that the cauſe of the diſengagement of vitriolic air in the one caſe, and inflammable in the other, is not ſo well ſolved. It has not been explained, upon the old theory, why the phlogiſton in one caſe unites with the acid, and forms ſulphur, and in the other flies off alone; neither has it been ſhewn, in the new theory, why the water ſhould not be decompoſed in the former inſtance, as well as the latter.

The further calcination of the iron by heat, or by expoſure of the ſolution to the air, is accounted for, in the new theory, from the abſorption of more vital air. The general fact, that a definite degree of calcination is neceſſary for the moſt perfect ſolution of metals in acids, depends on attractions which have not been experimentally reſolved; but which, in the way of conjecture, may be as eaſily accounted for by one theory as by the other.

Precipitates of iron.

Vitriol of iron is decompoſed by alkalis and by lime. Cauſtic fixed alkali precipitates the iron in deep green flocks, which are diſſolved by the addition of more alkali, and form a red tincture. The mild alkali does not rediſſolve the precipitate it throws down, which is of a greeniſh white colour. Diſtillation ſeparates the acid from martial vitriol, and leaves the brown calx of iron, called colcothar.

Colcothar.

Black fecula, precipitated by aſtringents.

Vegetable aſtringent matters, ſuch as nut-galls, the huſks of nuts, logwood, tea, &c. which contain the acid of galls hereafter to be deſcribed, precipitate a fine black fecula from martial vitriol, which remains ſuſpended for a conſiderable time in the fluid, by the addition of gum arabic. This fluid is well known by the

Ink; its nature doubtful.

he name of ink. It appears to conſiſt of the acid of galls, united to the calx of iron: but its nature has not been well determined; more eſpecially by an ex-mination of the contents of the fluid which remains fter the precipitate has been completely depoſited. The black fecula is not magnetical; but it is con-erted into a brown magnetic calx by heat. An ex-eſs of either of the three ancient mineral acids ren-ers ink colourleſs; but the acetous acid, or vinegar, oes not. Ink becomes blacker by expoſure to the ir, which acidifies more completely the principle ombined with the iron; but ancient writings become more and more yellow, in conſequence of the eſcape f the acid *. Their legibility may be reſtored by the ddition of infuſion of galls, or gallic acid. The beſt method of reſtoring the legibility of ancient writ-

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* Inks ſeem to fail chiefly on account of the ſmall proportion
id deſtructibility of the aſtringent principle, or gallic acid. Dr.
ewis recommends the following receipt for writing-ink (Com-
erce of Arts, page 391): One part martial vitriol, one part
wdered logwood, and three parts powdered galls, are to be
fuſed in one quart of vinegar, or white wine, or water, for
ch ounce of the vitriol, together with one ounce of gum ara-
c for each quart of the liquor; and ſhaken for four or five
nes a day, during ten or twelve days: after which it may be
canted for uſe.

On the above I muſt remark, that though vinegar affords a good
ack ink, yet Dr. Lewis has overlooked a great inconvenience
tending its uſe. It acts ſo ſtrongly upon the quills, that the
arpneſs of the extremity of a pen uſed with this ink ſoon
es off, and continually wants mending. A perfect theory of
k would probably lead to great improvements in this moſt
eful fluid.

Manufacture of Pruſſian blue.

ings * conſiſts in ſpreading a ſolution of the Pruſſian alkali thinly with a feather over the traces of the letters; and then to touch it gently, and as nearly upon or over the letters as can be done, with a diluted acid, by means of a pointed ſtick.

The beautiful pigment, well known in the arts by the name of Pruſſian blue, is likewiſe a precipitate afforded by martial vitriol. It has been made for conſiderably more than half a century; but its compoſition is not yet clearly aſcertained. The proceſs for making it is as follows: Calcine a mixture of equal parts of vegetable alkali and dried bullocks blood, until it ceaſes to emit either flame or ſmoke; then raiſe the fire, to give the maſs a low red heat. Throw the matter while red-hot into as many quarts of water as there were pounds of the original mixture, and boil it for half an hour. Decant the liquid, and waſh the coaly reſidue with more water, till it comes off almoſt inſipid. Add this water to the former, and evaporate the whole by boiling, until it be reduced again to the former number of quarts. This is the lixivium ſanguinis, or Pruſſian alkali; which, if added in a proper quantity to a ſolution of iron, precipitates it partly in the form of calx, and partly in the form of Pruſſian blue. If the marine acid be added to the precipitate, it diſſolves the calciform part, and leaves the Pruſſian blue much purer. Hence it appears that the whole of the alkali, in the uſual method of calcination with bullocks blood, or other animal ſubſtances, is not ſaturated with the colouring matter, but

Pruſſian alkali.

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* Blagden, in Philoſ. Tranſ. vol. lxxv. page 455.

that

hat the unſaturated part of the alkali precipitates part f the iron in the calciform ſtate; while the other art, combining with the colouring matter, falls down n the form of Pruſſian blue. For chemical purpoſes, he Pruſſian lye is produced, by boiling the alkali upon ruſſian blue ready formed. The calx of iron is thus eprived of the colouring matter by the alkali, to vhich it has a greater affinity, and which it only quits vhen there is another acid preſent to unite with the lkali; as in the juſt-mentioned inſtance of the ſolution of iron, where a double affinity takes place. The ruſſian alkali, prepared in either way, contains ſome on. It can be had pure in no other way than by irectly combining the pure colouring matter with a ure alkali.

Pruſſian alkali made for chemical purpoſes.

Acid of Pruſſian blue.

The habitudes of this colouring matter denote it o be an acid. If the Pruſſian alkali be boiled in a etort with weak vitriolic acid, the colouring matter omes over in the form of an inflammable air, which vill be abſorbed by water placed in the receiver. s a portion of vitriolic acid likewiſe comes over, a econd diſtillation is neceſſary to be made, with the ddition of chalk. The vitriolic acid, by this means orming ſelenite, is detained; while the Pruſſian acid aſſes over totally before one-fourth of the water is iſtilled off.

Combinations of Pruſſian acid.

The colouring matter of Pruſſian blue is not only eized by the fixed alkalis, but likewiſe by the volatile lkali, by lime, by magneſia, and by ponderous earth; vith which it forms peculiar compounds, capable of recipitating Pruſſian blue, by double affinity, from the olutions of iron in acids. Various metals likewiſe combine with it. Alkalis, or lime, combined with the Pruſſian acid, are uſed as teſts to aſcertain the preſence and quantity of iron in ſolution. But all the alkaline or earthy combinations, produced by applying thoſe ſubſtances to Pruſſian blue, contain iron, which falls down in the form of the blue precipitate when an acid is added. For this reaſon they cannot be uſed in accurate experiments, unleſs a previous trial has been made of the quantity a known proportion of the proof liquor is capable of precipitating.

Caution in uſing proof liquors.

Experiments on Pruſſian acid.

If the dephlogiſticated or aërated marine acid be mixed with the Pruſſian acid, the former reſumes the ſtate of common marine acid; while the latter acquires a much ſtronger ſmell, and appears to be more volatile. In this ſituation it does not form Pruſſian blue with the ſolutions of iron; but affords a green precipitate, which becomes blue by expoſure to the light, or by the addition of volatile vitriolic acid.

If martial vitriol be added to the dephlogiſticated or aërated marine acid, and a ſolution of Pruſſian alkali be poured in, the green precipitate which is formed is again diſſolved; but it may be precipitated of a blue colour by the addition of volatile vitriolic acid, or martial vitriol, or iron alone.

Theory.

In the inſtances laſt mentioned we may perceive that the effects depend on the dephlogiſtication or addition of vital air to the Pruſſian acid, accordingly as we adopt the ancient or the modern theory. The green precipitate, which may be conſidered either as dephlogiſticated Pruſſian blue, or as Pruſſian blue combined with vital air, becomes common Pruſſian

blue

Page 9, 168, 178.

Theory of the effects of aerated marine acid on Pruſſian acid.

blue by the action of light; which, as we have frequently had occaſion to remark, operates in many inſtances in a manner contrary to that of combuſtion; that is to ſay, it either adds phlogiſton, or expels vital air, or does both. By this action therefore the Pruſſian blue returns to its original ſtate. The addition of volatile vitriolic acid muſt produce a like effect; for this acid is phlogiſticated according to the old theory, or is deficient in vital air according to the new: it is therefore diſpoſed either to phlogiſticate the green precipitate, or to attract vital air from it; which is all that it requires to convert it into common Pruſſian blue. The ſame theories manifeſtly apply to the green precipitate, which is rediſſolved; for in whatever ſtate of combination it may be ſuppoſed to remain, as to the order or arrangement of the principles which are united in the fluid, the addition of volatile vitriolic acid, or common vitriol, or iron in the metallic ſtate, will impart phlogiſton, or attract vital air; the abſence of the one, or redundance of the other of which, is ſuppoſed, according to the reſpective theories, to cauſe the difference between it and Pruſſian blue.

Experiment.

If the Pruſſian acid be impregnated more ſtrongly with the dephlogiſticated or aërated marine acid, and hen expoſed to the action of light, it aſſumes new properties. It no longer combines with iron precipiated from its ſolutions; its ſmell is entirely different rom that which it before poſſeſſed; and now reſembles an aromatic oil, the greateſt part of it ſeparating from he water, at the bottom of which it flows in the orm of an oil. This fluid however is not inflammable.

IRON.

mable. By a gentle heat it riſes in the form of a vapour, not ſoluble in water: and in time it aſſumes the form of ſmall cryſtals. Pruſſian acid cannot be reſtored after it has undergone theſe changes. Their theory is not known.

Diſcovery of the component parts of Pruſſian acid.

Various experiments have been made to diſcover the component parts of the Pruſſian acid. If equal parts of pulverized charcoal and vegetable alkali be made red-hot for a quarter of an hour in a crucible, and ſome ſal ammoniac in ſmall pieces be then briſkly ſtirred down into the maſs, the ammoniacal vapours will ſoon ceaſe. The ignited matter being then thrown into water, affords a lixivium equal to the beſt which is made with blood. From theſe, and other experiments, it was concluded that its component parts are fixed air, volatile alkali, and the principle of inflammability, or phlogiſton. Later experiments appear to have decided the queſtion ſomewhat more accurately. When the acid has been converted, by means of the dephlogiſticated or aërated marine acid, into that ſtate which affords a green precipitate with iron, it emits alkaline air upon the addition of lime, or a pure alkali. If the lime, or alkali, be afterwards ſaturated by the addition of ſome other acid, the Pruſſian acid is not diſengaged, or reſtored, but is no where found; hence it follows, that the alkaline air was one of the principles of the Pruſſian acid, which is deſtroyed: and as the lime or alkali uſed in this decompoſition is found to be in a mild ſtate, that is to ſay, combined with fixed air, though it did not contain that ſubſtance before; it is clear that the other principle of the Pruſſian acid is fixed air.

The

Component parts of Pruſſian acid.

The common Pruſſian acid conſiſts therefore of volatile alkali, united with the baſe of fixed air, or that ſubſtance which, in combination with vital air, forms the acid called fixed air. When the Pruſſian acid receives vital air, and is converted into the ſtate proper to afford the green precipitate, it then appears, to conſiſt of the ſame principles as the mild or concrete volatile alkali, though probably in a different order of combination; and this order ſeems to be deranged by the addition of the lime, or the fixed alkali, which attracts thoſe principles that form fixed air, at the ſame time that the principles which form volatile alkali fly off in the elaſtic ſtate.

The component parts of Pruſſian acid will conſequently be phlogiſticated air, inflammable air, and fixed air, or its baſe; all which are afforded by animal ſubſtances: but they do not form this peculiar combination in any caſe yet known, excepting that in which an alkali is preſent when thoſe ſubſtances are decompoſed by fire *.

Action of nitrous acid on iron.

Concentrated nitrous acid acts very ſtrongly upon iron filings, much nitrous air being diſengaged at the ſame time. The ſolution is of a reddiſh brown, and depoſits the calx of iron after a certain time; more eſpecially if the veſſel be left expoſed to the air. A diluted nitrous acid affords a more permanent ſolution

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* For a fuller account of this ſubject conſult Scheele's Eſſays; the Opuſcula, or Chemical Eſſays, of Bergman; and the Annales de Chimie, vol. i; the latter of which contains an abſtract of a valuable memoir of Berthollet, read before the Royal Academy of Sciences at Paris, in the year 1787.

of

IRON.

of iron, of a greeniſh colour, or ſometimes of a yellow colour: neither of the ſolutions affords cryſtals; but they depoſit the calx of iron by boiling, at the ſame time that the fluid aſſumes a gelatinous appearance. This magma, by diſtillation, affords fuming nitrous acid, much nitrous air, and ſome phlogiſticated air; a red calx being left behind, which, in all probability, retains moſt of the vital air of the acid.

Precipitates of iron from nitrous acid.

If vegetable alkali be added to the nitrous ſolution of iron, a brown precipitate falls down; of which a ſmall quantity is rediſſolved by the alkali. Mild vegetable alkali ſeparates a yellowiſh calx, which ſoon becomes of a beautiful orange red colour. If the mixture be agitated during the effervefcence, the precipitate is rediſſolved in much greater quantity than by the pure vegetable alkali; doubtleſs by the medium of the fixed air. This ſolution is known by the name of Stahl's martial alkaline tincture, and is of a fine red colour, which however is impaired by time. Pure volatile alkali ſeparates a deep green and almoſt black precipitate from the nitrous ſolution of iron. The mild volatile alkali rediſſolves the iron, which it ſeparates from the acid; and forms an alkaline tincture of a more lively colour than that of Stahl.

Martial alkaline tinctures.

Action of marine acid on iron.

Diluted marine acid rapidly diſſolves iron, at the ſame time that a large quantity of inflammable air is diſengaged, and the mixture becomes hot. In this, as well as in the vitriolic ſolution of iron, the ſame quantity of alkali is ſaid to be required to ſaturate the acid as before the ſolution; whence it is inferred that the acid is not decompoſed, but that the calcination

tion is effected by the vital air of the water: whence alſo it appears to follow, that the inflammable air muſt be afforded from the decompoſed water, and not from the metal. It muſt however be remarked, that this fact, as well as moſt of thoſe upon which the rejection of phlogiſton, or the inflammable principle, is grounded, are controverted by the philoſophers who maintain the exiſtence of that principle.

Marine ſolution of iron.

The marine ſolution of iron is of a yellowiſh green colour, and is much more permanent than the ſolutions of that metal in the vitriolic or nitrous acids; though, like all the other ſolutions of iron, it depoſits its metal by expoſure to the air. By evaporation it aſſumes the conſiſtence of ſyrup, in which needle-formed and deliqueſcent cryſtals appear. Some chemiſts affirm, that the acid quits the iron by diſtillation, though much more difficultly than either the nitrous or vitriolic acid; but this intereſting experiment has not been made ſince the improvements of chemiſtry have led philoſophers to attend to ſuch products as appear in the permanently elaſtic ſtate.

Precipitates.

The marine ſolution of iron is decompoſed by lime and by alkalis; but the precipitates are more eaſily reduced to the metallic ſtate than thoſe afforded by other acids. Liver of ſulphur, hepatic air, and aſtringents, decompoſe this, as well as the other ſolutions of iron; and the pure Pruſſian alkali throws down a very fine blue precipitate.

Action of fixed air on iron:

Fixed air, diſſolved in water, combines with a conſiderable quantity of iron, in proportion to its maſs. Vinegar ſcarcely diſſolves it, unleſs by the aſſiſtance of the air.

—and vinegar.

IRON.

Action of earths, &c. on iron.

In the dry way, this metal does not combine with earths, unleſs it be previouſly calcined; in which caſe it aſſiſts their fuſion, and imparts a green colour to the glaſs. It appears to combine with alkalis by fuſion. Nitre detonates ſtrongly with it, and becomes alkalized. Sal ammoniac is decompoſed by it. Two parts of iron filings, triturated with one part of ſal ammoniac, and expoſed to diſtillation, afford about one part of liquid volatile alkali, contaminated by a ſmall portion of iron. Some inflammable air comes over in this diſtillation, either from the iron, or from the water contained in the ſal ammoniac: the reſidue conſiſts of iron, united to marine acid. A medical preparation is made by ſubliming ſal ammoniac from a ſmall portion of iron filings; which gives part of the ſalt a yellow colour. The calx of iron decompoſes ſal ammoniac by ſeizing its acid, even in the cold.

Combination of iron with ſulphur in the humid way.

Sulphur combines very readily with iron, in the dry, and even in the humid way, though neither of theſe ſubſtances is ſcarcely at all ſoluble in water. A mixture of iron filings and flowers of ſulphur being moiſtened, or made into a paſte, with water, becomes hot, ſwells, adheres together, breaks, and emits watery vapours of an hepatic ſmell. If the mixture be conſiderable in quantity, as for example, one hundred pounds, it takes fire in twenty or thirty hours, as ſoon as the aqueous vapours ceaſe. This effect may be explained without difficulty in a general way, though the circumſtances require to be more minutely examined:—Iron, ſulphur, and water, are placed in contact. The iron is very ſparingly ſoluble in water *;

Spontaneous inflammation.

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* Annales de Chimie, vol. i. 220.

and the ſulphur is probably ſoluble in a ſmall degree, as may be judged by its becoming ſoft in that fluid. In the ancient theory, it may be ſaid that the ſulphur combines with the calx of the iron, and expels its inflammable air or phlogiſton. The heat muſt be deduced, in any theory, from the change of capacity, or rapid commotion, produced in the act of union. This heat volatilizes part of the ſulphur, together with the inflammable air; and if the temperature be ſufficiently elevated, theſe ſubſtances will take fire, at the moment of their extrication, by the aſſiſtance of the air of the atmoſphere. In the new theory, the explanation will be nearly the ſame. The iron and the ſulphur, being conſidered as ſimple ſubſtances, tend to combine with each other, through the medium of vital air, which calcines the iron, and is ſuppoſed to be afforded by decompoſition of the water. The ſame decompoſition extricates inflammable air from the water. This, together with the ſulphur, forms hepatic air; which, flying off at the temperature of ignition, takes fire by combination with the air of the atmoſphere. In this theory it may further be added, that, as ſulphur and water, in contact, at an elevated temperature, afford inflammable air, which is explained by the ſuppoſition of vital air combining with the ſulphur, there would be an increaſe of inflammation from this cauſe. Some doubt however may be entertained, whether ſulphur be more combuſtible than inflammable air at any temperature, ſince hepatic air depoſits ſulphur when detonated with vital air; which muſt, in all probability, depend on the latter being leſs combuſtible at the temperature of inflammation. On the

Page 136.

Theory of the inflammation of iron and ſulphur:

— by the antiphlogiſtic hypotheſis.

IRON.

whole it appears, that facts and obſervations are wanting, rather than probable theories; and that it is ſcarcely neceſſary to purſue this inquiry more minutely in the way of argumentative diſquiſition. The ſpontaneous combuſtion of iron and ſulphur with water, is evidently an effect of the ſame kind as the decompoſition of pyrites.

Page 140.

Union of ſulphur with iron in the dry way.

Sulphur combines very readily with iron by fuſion; and produces a compound of the ſame nature as the pyrites, and exhibiting the ſame radiated ſtructure when broken. If a bar of iron be heated to whiteneſs, and then touched with a roll of ſulphur, the two ſubſtances combine, and drop down together in the fluid ſtate. It is neceſſary that this experiment ſhould be made in a place where there is a current of air to carry off the fumes; and the melted matter, which may be received in a veſſel of water, is of the ſame nature as that produced by fuſion in the common way, excepting that a greater quantity of ſulphur is fuſed by the contact of the bar of iron. The experiment of combining iron and ſulphur together by fuſion, has not been made with an attention to the volatile products, if any be extricated. As neither of theſe ſubſtances contains water, and both are ſuppoſed, in the new theory, to be ſimple bodies, the experiment might, perhaps, afford an intereſting reſult.

Phoſphorus and iron.

If equal parts of phoſphoric glaſs, and iron clippings, together with one-ſixteenth of a part of pulverized charcoal, be fuſed together, the mixture is very brittle, white in its fracture, and of a ſtriated and granulated texture. This combination of iron with phoſphoric acid is found in the iron produced from bog ores, which abound in the remains of decayed vegetables. It is the cauſe of brittleneſs in the iron when cold; which occaſions that kind of iron to be called cold ſhort iron by the workmen. Phoſphorated iron was at firſt taken to be a peculiar metal; and was called ſiderite by Bergman.

Cold ſhort iron.

Siderite.

Iron unites with gold, ſilver, and platina. When heated to a white heat, and plunged in mercury, it becomes covered with a coating of that metal. Long trituration of mercurial amalgams likewiſe cauſes a coating to adhere to the ends of iron peſtles; and ſmall ſteel ſprings, kept plunged beneath the ſurface of mercury in certain barometers, have become brittle in proceſs of time: hence there appears to be a weak action between mercury and iron. Iron and tin very readily unite together; as is ſeen in the art of tinning iron veſſels, and in the fabrication of thoſe uſeful plates of iron, coated with tin, which are generally diſtinguiſhed by the ſimple name of tin alone. The chief art of applying theſe coatings of tin conſiſts in defending the metals from calcination by the acceſs of air. After the iron plates are ſcraped, or rendered very clean by ſcouring with an acid, they are wetted with a ſolution of ſal ammoniac, and plunged into a veſſel containing melted tin; the ſurface of which is covered with pitch or tallow, to preſerve it from calcination. The tin adheres to and intimately combines with the iron to a certain depth, which renders the tinned plates leſs diſpoſed to harden by hammering, than before, as well as much leſs diſpoſed to alter, by the united action of air and moiſture. The proceſs for

Metallic combinations.

Tinning of iron plates.

for tinning of iron veſſels does not eſſentially differ from that which has already been deſcribed of copper veſſels. Iron does not unite with biſmuth, at leaſt in the direct way. As nickel cannot be purified from iron without the greateſt difficulty, it may be preſumed that theſe ſubſtances would readily unite, if the extreme infuſibility of both did not preſent an obſtacle to the chemical operator. Arſenic forms a brittle ſubſtance in its combination with iron. This ſemi-metal, which is ſo abundant in the mineral kingdom, is ſaid to be the cauſe of the brittleneſs which ſome ſpecimens of iron poſſeſs when hot, though malleable when cold. Iron, thus contaminated, is diſtinguiſhed by workmen by the name of red ſhort iron. Cobalt forms a hard mixture with iron, which is not eaſily broken. The inflammability and volatility of zinc preſent an obſtacle to its combination with iron. It is not improbable, however, but that clean iron filings would unite with zinc, if that metal were kept in contact with them for a certain time, in a heat not ſufficient to cauſe it to riſe; for it has been found that zinc may be uſed in the operation of coating iron in the ſame manner as tin. Antimony unites with iron, and forms a hard brittle combination, which yields, in a ſlight degree, to the hammer. The combination of ſulphur, and the regulus of antimony, which is commonly known by the name of antimony, is decompoſed by virtue of the greater affinity of the iron to the ſulphur. For this purpoſe, five ounces of the points of nails from the farriers may be made red hot in a crucible; one pound of pulverized ore of antimony muſt then be thrown into the crucible, and the

Combinations of iron with metallic ſubſtances.

Combinations of iron with metallic ſubſtances.

the heat quickly raiſed to fuſe the whole. When the fuſion is perfect, an ounce of nitre in powder may be thrown in, to facilitate the ſeparation of the ſcoriæ. After the maſs is cooled, the antimony is found ſeparate at the bottom of the crucible, while the iron remains in combination with the ſulphur and alkali. If the proportion of the iron be conſiderably greater than five ounces to the pound of antimonial mineral, the regulus will be alloyed with iron. Manganeſe is almoſt always united with iron in the native ſtate. Wolfram forms a brittle whitiſh-brown hard alloy, of a compact texture, when fuſed with white crude iron.

The habitudes of iron with the regulus of molybdena are not known.

Native iron and its ores.

Iron is the moſt diffuſed, and moſt abundant, of metallic ſubſtances. Few mineral bodies, or ſtones, are without an admixture of this metal. Sands, clays, and the waters of rivers, ſprings, rain, or ſnow, are ſcarcely ever perfectly free from it. The parts of animal and vegetable ſubſtances likewiſe afford iron in the reſidues they leave after incineration. It has been found native, in large maſſes, in Siberia *, and in the internal parts of South America. This metal however in its native ſtate is ſcarce: moſt iron is found in the calciform ſtate, in ochres, bog ores, and other friable earthy ſubſtances, of a red, brown, yellow, or black colour. The hæmatites, or blood ſtones, are likewiſe calciform ores of iron: theſe are either of a red colour, or blue, yellow, or brown. This uſeful

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* See Bergman's Eſſays; Magellan's improved edition of Cronſtedt's Mineralogy; and the Philoſ. Tranſ. lxxviii. 37.

Ores of iron.

metal is ſo abundant, that whole mountains are compoſed of iron ſtone; whereas, other metals uſually run in ſmall veins. Beſides the calciform ores of iron, which are either nearly pure, or elſe mixed with earths, as in ſpars, jaſper, boles, baſaltes, &c. iron is mineralized with ſulphur, as in the pyrites; with arſenic, in the white pyrites; or with both. An iron ore is likewiſe found, of a blue colour, and powdery appearance, which is thought to be of the ſame nature as Pruſſian blue. The coaly iron ores contain bitumen. The magnet, or loadſtone, is an iron ore, whoſe conſtitution has not yet been accurately examined. Iron is alſo found in combination with the vitriolic acid, either diſſolved in water, or in the form of vitriol.

Humid analyſis of iron ores.

To analyſe the ores of iron in the humid way, they muſt be reduced to a very ſubtle powder, and repeatedly boiled in marine acid. If the ſulphureous ores ſhould prove ſlow of ſolution, a ſmall quantity of nitrous acid muſt be added to accelerate the operation. The iron being thus extracted, the inſoluble part of the matrix only will remain. Pruſſian alkali, being added to the decanted ſolution, will precipitate the iron in the form of Pruſſian blue. This precipitate, when waſhed and dried, will be equal in weight to ſix times the quantity of metallic iron it contains; and from this iron four parts in the hundred muſt be deducted, to allow for the iron which is contained in the Pruſſian alkali itſelf. But as this alkali, and every other preparation containing the Pruſſian acid, does not conſtantly afford the ſame quantity of iron, the moſt exact way, in the uſe of ſuch preparations, conſiſts

Page 302.

Ores of iron.

conſiſts in previouſly diſſolving a known quantity of ron in vitriolic acid; and precipitating the whole by he addition of the Pruſſian alkali. This reſult will fford a rule for the uſe of the ſame alkali in other olutions. For as the weight of the precipitate obained in the trial experiment, is to the quantity of ron which was diſſolved and precipitated; ſo is the weight of the precipitate obtained from any other olution, to the quantity of iron ſought.

If the iron be united to any conſiderable proportion of zinc or manganeſe, the Pruſſian blue muſt be calcined to redneſs, and treated with pale nitrous acid, which will take up the calx of zinc. The manganeſe may then be diſſolved by nitrous acid, with the addition of ſugar; and the remaining iron being diſſolved by marine acid, and precipitated by mild mineral alkali, will afford 225 grains of precipitate for every 100 grains of metallic iron.

Analyſis in the dry way.

To examine the ores of iron in the dry way, the only requiſite is fuſion, in contact with charcoal. For this purpoſe, eight parts of pulverized glaſs, one of calcined borax, and half a part of charcoal, are to be well mixed together. Two or three parts of this flux, being mixed with one of the pounded ore, and placed in a crucible, lined with a mixture of a little clay and pounded charcoal, with a cover luted on, is to be urged with the ſtrong heat of a ſmith's forge for half an hour. The weight of the ore, in this experiment, ſhould not exceed 60 grains. Other proceſſes for determining the contents, or metallic product, of iron ores, are inſtituted by performing the ſame operations

IRON.

rations in the ſmall, as are intended to be uſed in the large way.

Smelting of iron in the large way.

In the large iron works, it is uſual to roaſt, or calcine the ores of iron, previous to their fuſion; as well for the purpoſe of expelling ſulphureous or arſenical parts, as to render them more eaſily broken into fragments of a convenient ſize for melting. The mineral is melted, or run down, in large furnaces, from 16 to 30 feet high; and variouſly ſhaped, either conical or elliptical, according to the opinion of the iron maſter. Near the bottom of the furnace is an aperture for the inſertion of the pipe of large bellows, worked by water or ſteam, or of other machines for producing a current of air; and there are alſo holes at proper parts of the edifice, to be occaſionally opened, to permit the ſcoriæ and the metal to flow out, as the proceſs may require. Charcoal, or coke, with lighted bruſhwood, is firſt thrown in; and when the whole inſide of the furnace has acquired a ſtrong ignition, the ore is thrown in by ſmall quantities at a time, with more of the fuel, and commonly a portion of limeſtone, as a flux: the ore gradually ſubſides into the hotteſt part of the furnace, where it becomes fuſed; the earthy part being converted into a kind of glaſs; while the metallic part is reduced by the coal, and falls through the vitreous matter to the loweſt place. The quantity of fuel, the additions, and the heat, muſt be regulated, in order to obtain iron of any deſired quality; and this quality muſt likewiſe, in the firſt product, be neceſſarily different, according to the nature of the parts which compoſe the ore.

The

States of iron.

The three kinds of crude iron.

The iron which is obtained from the ſmelting furnaces is not pure; and may be diſtinguiſhed into three ſtates:—white crude iron, which is brilliant in its fracture, and exhibits a cryſtallized texture, more brittle than the other kinds, not at all malleable, and ſo hard as perfectly to withſtand the file: grey crude iron, which exhibits a granulated and dull texture when broken; this ſubſtance is not ſo hard and brittle as the former, and is uſed in the fabrication of artillery, and other articles which require to be bored, turned, or repaired: and black caſt iron, which is ſtill rougher in its fracture; its parts adhere together leſs perfectly than thoſe of the grey crude iron: this is uſually fuſed again with the white crude iron.

Refining of iron.

Whenever crude iron, eſpecially the grey ſort, is fuſed again with contact of air, it emits ſparkles, loſes weight, and becomes leſs brittle. In order to convert it into malleable iron, it is placed on a hearth, in the midſt of charcoal, urged by the wind of two pair of bellows. As ſoon as it becomes fuſed, a workman continually ſtirs it with a long iron inſtrument. During the courſe of ſeveral hours it becomes gradually leſs fuſible, and aſſumes the conſiſtence of paſte. In this ſtate it is carried to a large hammer, the repeated blows of which drive out all the parts that ſtill partake of the nature of crude iron ſo much as to retain the fluid ſtate. By repeated heating and hammering more of the fuſible iron is forced out; and the remainder, being malleable, is formed into a bar, or other form, for ſale. Crude iron loſes upwards of one-fourth of its weight in the proceſs of refining.

Purified,

IRON.

Bar iron.

Purified, or bar iron, is ſoft, ductile, flexible, malleable, and poſſeſſes all the qualities which have been enumerated in this chapter, as belonging excluſively to iron. When a bar of iron is broken, its texture appears fibrous; a property which depends upon the mechanical action of the hammer, while the metal is cold. Ignition deſtroys this fibrous texture, and renders the iron more uniform throughout; but hammering reſtores it.

Iron converted into ſteel by cementation.

If the pureſt malleable iron be bedded in pounded charcoal, in a covered crucible, and kept for a certain number of hours in a ſtrong red heat (which time muſt be longer or ſhorter, according to the greater or leſs thickneſs of the bars of iron), it is found that by this operation, which is called cementation, the iron has gained a ſmall addition of weight, amounting to about the hundred and fiftieth, or the two hundredth part; and is remarkably changed in its properties. It is much more brittle and fuſible than before. Its ſurface is commonly bliſtered when it comes out of the crucible; and it requires to be forged, to bring its parts together into a firm and continuous ſtate. This cemented iron is called ſteel. It may be welded like bar iron; but its moſt uſeful and advantageous property is that of becoming extremely hard when ignited, and plunged in cold water. The hardneſs produced is greater in proportion as the ſteel is hotter, and the water colder. The colours which appear on the ſurface of ſteel ſlowly heated, are yellowiſh white, yellow, gold colour, purple, violet, deep blue, yellowiſh white; after which the ignition takes place. Theſe ſigns direct the artiſt in tempering or reducing the

Hardening.

Tempering.

The proceſſes for hardening and tempering of ſteel.

the hardneſs of ſteel to any determinate ſtandard. If ſteel be too hard, it will not be proper for tools which are intended to have a fine edge, becauſe it will be ſo brittle that the edge will ſoon become notched; if it be too ſoft, it is evident that the edge will bend or turn. Some artiſts ignite their tools, and plunge them in cold water; after which, they brighten the ſurface of the ſteel upon a ſtone: the tool being then laid upon charcoal, or upon the ſurface of melted lead, or placed in the flame of a candle, gradually acquires the deſired colour; at which inſtant they plunge it into water. Others, eſpecially in larger inſtruments, plunge the tool into very cold water as ſoon as it is completely ignited; and, when it ceaſes to be luminous beneath the water, they take it out, rub it quickly with a file, or on a plate covered with ſand, that it may acquire a white ſurface. The heat which the metal ſtill poſſeſſes ſoon begins to produce the ſucceſſion of colours. If a hard temper be deſired, the piece is dipped again, and ſtirred about in the cold water as ſoon as the yellow tinge appears. If the purple appear before the dipping, the temper will be fit for gravers, and tools uſed in working upon metals; if dipped while blue, it will be proper for ſprings, and for inſtruments uſed in the cutting of ſoft ſubſtances, ſuch as cork, leather, and the like; but if the laſt pale colour be waited for, the hardneſs of the ſteel will ſcarcely exceed that of iron. It is circumſtance worthy of remark, that ſteel has a leſs ſpecific gravity when hardened than when ſoft; but there are no circumſtances, upon which a probable connection between theſe two properties, namely the increaſed hardneſs, and the diminiſhed ſpecific gravity, can be made out.

The uſual time required for the cementation of ſteel, is from ſix to ten hours. If the cementation be continued too long, the ſteel becomes porous, brittle, of a darker fracture, more fuſible, and incapable of being forged or welded. On the contrary, ſteel cemented with earthy infuſible powders, is gradually reduced to the ſtate of forged iron again. Simple ignition produces the ſame effect; but is attended with calcination of the ſurface. The texture of ſteel is rendered more uniform by fuſing it before it is made into bars: this is called caſt ſteel; and is rather more difficultly wrought than common ſteel, becauſe it is more fuſible, and is diſperſed under the hammer if heated to a white heat.

Caſt ſteel.

Compariſon of ſteel and crude iron.

When we conſider the operations by which crude iron is brought into the malleable ſtate, then converted into ſteel, and afterwards into a fuſible metal, which is not malleable; we may perceive that ſteel-making is a kind of inverſion of the proceſs of refining iron, as practiſed in the firſt inſtance. When the calx of iron is mixed together in the ſmelting furnace, with combuſtible matter and glaſs, it will either be completely or partially revived, according to the management of the proceſs. Much of the coal will however be ſo enveloped with the vitreous matter as to remain unburned: and the reduced iron, with which it may be in contact, will be in the ſame ſituation as forged iron in the cementing pot; that is to ſay, it will be in contact with coal at a very elevated temperature, and defended from the air. From the

7

the great infuſibility of iron, it may reaſonably be concluded that the reduced metal does not flow into the bottom of the furnace, until the charcoal has converted it into a fuſible matter ſimilar to ſteel, by the ſame action which takes place in cementation, whatever that action may be. Hence it muſt follow, that the various ſpecimens of crude or caſt iron will differ in their qualities, as well on account of the degree of cementation they have undergone, as the degree of reduction which has taken place among the metallic parts, which are carried down, and form the whole maſs. Since the coal, in the proceſs of cementation, communicates or adds weight to the iron; and ſince crude iron, as well as ſteel, exhibits ſparkles, and is more eaſily burned than other iron: it may therefore be concluded that, in the proceſs of refining, that part of the inflammable ſubſtance which had united with the metal is burned, and leaves the iron much leſs fuſible than before. Stirring the maſs multiplies the contacts of the air with the burned ſubſtances; theſe ſurfaces of contact will therefore ſucceſſively afford thin coats of infuſible metal. In this manner it is found, that if a large piece of crude iron be expoſed to heat in a wind furnace, the external part will be deprived of its fuſibility during the time required to produce a ſtrong heat in the whole maſs; and the internal part will be melted, and run out, leaving the ſhell behind. Iron which is of the conſiſtence of paſte may therefore be conſidered, like any other paſte, as a mixture of a fluid with a ſolid. It will be eaſily underſtood that the forging will bring the parts of difficult fuſion together, and extrude the leſs refined and fluid

Page 318.

Conſideration of the effects of heat in refining

IRON.

fluid parts: it will alſo be evident that this operation is not likely to drive out the whole of the fuſible matter. When the iron has arrived at that ſtate wherein the quantity of fibre or tough iron is ſufficient to anſwer the mechanical purpoſes to which it is intended to be applied, the artiſt will conſider it as ſufficiently refined; and the reſidue of fuſible iron contained in the bar anſwers, in all probability, the valuable purpoſe of connecting theſe infuſible maſſes together. Thus we find that forged iron appears as if covered with a varniſh, when urged to a white heat; we find that this varniſh is more abundant in ſteel; and that iron and ſteel may be reſpectively welded together by application in this ſtate; an effect which it would be very difficult to account for, in this moſt infuſible of metals, if it were not for ſuch an admixture. But caſt ſteel, ſteel over-cemented, and crude iron, appear to be in the ſtate of all other metals, platina excepted. They cannot be welded, becauſe welding implies a partial fuſion; or an effect ſimilar to the gluing or uniting of ſolids by the application of a fluid, which afterwards becomes conſiſtent. And if it be true that platina poſſeſſes this valuable property, it ſeems reaſonable to infer that it muſt alſo conſiſt of two metallic ſubſtances of different degrees of fuſibility.

Probable cauſe of the property of welding.

Platina.

Crude iron and ſteel.

Crude iron, and ſteel of an uniform texture, conſiſt therefore of a fuſible combination of iron with the combuſtible ſubſtance of the coal, or ſomething which is imparted from it; the crude iron differing from the ſteel ſimply in being over-cemented, and leſs pure, on account of the admixture of metallic calx, which can ſcarcely, perhaps, be avoided in the large

Proceſſes for refining crude iron, and making ſteel in a direct way.

proceſs. It appears therefore that crude iron muſt paſs through the ſtate of ſteel before it can become forged iron; and conſequently that the fabrication of ſteel from this laſt is a circuitous proceſs, which can only be repaid by the abſence of thoſe unreduced parts which may exiſt in the crude iron. At ſome orges, however, where the ore, the flux, the fuel, and the management, are adapted to each other, the produce affords ſteel, when duly refined. At other manufactories, the crude iron is either refined, or converted into ſteel, by running it into thin plates, which re ſtratified with charcoal, and burned in a cloſe furnace. In this way, the metal is refined by degrees, without undergoing fuſion; and if the heat be raiſed o that of cementation, the iron will not only be educed, but converted into ſteel. In the forges of Carinthia the grey crude iron is alſo converted either into ſoft iron, or ſteel, according to the management f a ſomewhat ſimilar proceſs. The iron is fuſed in large melting pot; and a ſmall quantity of water beg thrown upon the ſurface of the metal, cauſes a thin ate to congeal, which is taken off; and, by continuing he operation, the greateſt part of the fuſed iron beomes converted into plates. To produce ſteel, theſe ates are again fuſed, and kept a long time in an evated heat; at the ſame time that the metal is efended from the contact of the air by a ſufficient uantity of the vitreous ſlag. To produce ſoft iron, e plates are expoſed to a continued roaſting, while e air is conſtantly renewed by means of two pair of llows. The extenſive ſurface of the plates renders it unneceſſary to uſe that agitation, or ſtirring, which is required when fuſed crude iron is refined. In theſe proceſſes it is evident that the ſame matter in the crude iron, which it obtained in the ſmelting furnace, is employed, and ſupplies the place of the charcoal of cementation in forming the ſteel; and, on the other hand, that this ſubſtance, which prevented the crude iron from being ſoft, tough, and infuſible, is burned away, together with a portion of the iron itſelf, while the remainder is left in a much purer ſtate.

The exiſtence of plumbago in crude iron and ſteel; aſcertained in the dry way.

Theſe are the facts obſerved at the furnaces. But the obſervations and inquiries of the chemiſt muſt be carried farther, in order to determine what it is that iron gains or loſes at the time of its converſion into its various ſtates. It is found that crude iron approaches towards the ſoft ſtate, not only by heating with expoſure to air, which burns the combuſtible addition, but likewiſe by fuſion, without the free acceſs of air. In this caſe, when the fuſion has been complete, and the cooling gradual, it is found that a black ſubſtance is thrown up to its ſurface, which is more abundant the greyer or blacker the iron; and the ſame black ſubſtance is obſerved to coat the ladles of forged iron, which are uſed to take out the metal, and pour it into moulds for caſting ſhot, and other articles. It appears therefore that the heated iron, like other heated fluids, is capable of holding a larger quantity of matter in ſolution than when cold; and that a portion of this black ſubſtance ſeparates during the cooling, whether by the gradual effect of ſurrounding bodies or by the contact of the ladle, in the ſame manner as various ſalts are ſeparated, in part, from water by a diminution of temperature. From chemical analyſis, as well as from its obvious characters, this black ſubſtance is found to be plumbago, or the material uſed to make pencils, and commonly known by the name of black lead.

Plumbago extricated from iron in the humid way.

The preſence of this black matter is likewiſe exhibited by diſſolving ſteel, or crude iron, in acids, in which plumbago is inſoluble, and therefore remains behind in the form of a powder. Hence likewiſe is deduced the cauſe of the black ſpot which remains upon ſteel, or crude iron, after its ſurface has been corroded by acids; for this ſpot conſiſts of the plumbago which remains after the iron has diſappeared by ſolution.

Quantities of plumbago, and of inflammable air, afforded by various kinds of iron.

Solution in the vitriolic or marine acids, not only exhibits the plumbago contained in iron, but likewiſe poſſeſſes the advantage of ſhewing the ſtate of its reduction by the quantity of inflammable air which is diſengaged: for whether this aërial fluid be ſupplied by the phlogiſton of the iron, or from the decompoſed water, it is agreed on all hands that its quantity, in like circumſtances, is proportional to that of the iron which is converted into calx. There are conſiderable differences between the various products of the ſmelting furnace in theſe reſpects; but it is found that the white crude iron affords the leaſt quantity of inflammable air in proportion to its bulk, and leaves a moderate portion of plumbago; the grey crude iron affords more inflammable air, and more plumbago, than the white; and the ſofteſt bar iron affords moſt inflammable air of any, and little or no plumbago. The quantities of inflammable air [*], at a medium, by ounce meaſures, were 62, afforded by 100 grains of the white crude iron; 71 by the grey crude iron; and 77 by the malleable iron.

Degrees of reduction and cementation in iron.

Hence it may be inferred that, in the white crude iron, the proceſſes of reduction and cementation are both carried to a leſs extent than in the grey crude iron, which is produced by means of a ſtronger heat, excited with a larger quantity of fuel: and that the reduction of grey crude iron is ſtill leſs perfect than that of the ſoft bar iron; though this laſt, by the refining in an open veſſel, is ſo far from being more cemented, that it ſcarcely contains any plumbago at all.

Inaccuracies.

It muſt be admitted, however, that the ſolution in acids ſerves only to ſupport theſe general concluſions, in conjunction with the facts obſerved in the dry proceſſes; but cannot accurately ſhew either the quantities of inflammable air or plumbago afforded by the ſeveral kinds of iron. For the plumbago, as it becomes diſengaged, floats on the top of the vitriolic acid; where it gradually diſappears, though inſoluble in that acid. It muſt therefore be taken up by the inflammable air; and it is found that the volume of this air is diminiſhed by the abſorption. Hence there is a double ſource of inaccuracy from the loſs of plumbago, and the contraction of the inflammable air.

Plumbago.

As plumbago appears to be a compound of iron and combuſtible matter, and as the properties and effects of iron, in its various ſtates, cannot be well underſtood without a reference to thoſe of this ſubſtance, it will be expedient to give an account of it in this place, inſtead of referring it to the next ſection.

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[*] Acad. Par. 1786, pages 166, 167. The numbers in the text are given as a rough meaſure; for, in fact, there can be no medium.

Characters of plumbago.

Plumbago, or black lead, is a well-known ſubſtance, of a black colour, and ſhining appearance, when cut. Its texture is rather ſcaly; but its fracture exhibits a granular and dull appearance. None of the ſpecimens have any conſiderable hardneſs. This mineral is found in England, Germany, France, Spain, and Africa; but the ſort beſt adapted for making pencils comes chiefly from Borrowdale in Cumberland. For this purpoſe, it is carefully ſawed into narrow ſlips, or pieces, not more than one-tenth of an inch thick; which are glued between two half cylinders of cedar wood. An inferior kind of pencils is made by the Jews, by mixing the powder or ſawduſt with gum arabic, or fuſing it with reſin or ſulphur; and preſſing or pouring it into the cavities of reeds. The powder of plumbago, with three times its weight of clay, and ſome hair, makes an excellent coating for retorts; and the black lead or Heſſian crucibles are compoſed of the ſame materials.

Habitudes.

Plumbago is not ſubject to alteration by expoſure to the action of air or water; and it is inſoluble in acids. In cloſed veſſels it is either entirely, or nearly, unalterable by the ſtrong heat of a furnace; but by continued ignition, and occaſional ſtirring in a ſhallow veſſel, under a muffle, it is gradually diſſipated, or burned, leaving a reſidue of calx of iron, of about one-tenth of the original weight. It detonates with nitre in a red heat; ten parts of this ſalt are required

Experiments tending to diſcover the component parts of plumbago.

quired to one of plumbago before the whole will be decompoſed, and exhibit no reſidue of plumbago when the alkali is diſſolved in water. The aërial product of this detonation is found to conſiſt of a mixture of one-third fixed air; and the reſt air which maintains combuſtion: the alkali contains fixed air; and ſome of the nitre is driven up by the heat. In order to ſhew that the fixed air came from the plumbago, and not from the nitre, the firſt analyſer* of this ſubſtance detonated tin, antimony, and ſulphur, reſpectively, with nitre, and obtained no fixed air: and, ſtill more to place the inference beyond a doubt, he expoſed plumbago to diſtillation, with twice its weight of dry acid of arſenic: the acid was reduced to the ſtate of white calx and ſublimed; and pure fixed air came over. Similar reſults were had with the calces of mercury and lead; the metals were revived, and fixed air was expelled. When pulverized plumbago was diſtilled with cauſtic fixed alkali by a ſtrong heat, the volatile product was inflammable air; and the remaining alkali contained fixed air.

Phlogiſtic theory.

From theſe, and other facts, he concluded, that plumbago is a compound of phlogiſton and fixed air, with a little iron, which he ſuppoſed to be accidental. The exiſtence of the phlogiſton was judged to be proved by its detonation with nitre, as well as by the revival of the acid of arſenic and the metallic calces, and the extrication of inflammable air by alkali: he inferred the quantity of phlogiſton in this ſubſtance to be twice as much as in charcoal; becauſe it requires twice the quantity of nitre for its detonation. The preſence of fixed air was deduced from the aërial products in all the diſtillations but the laſt; and from the mild ſtate of the alkalis, in thoſe trials wherein they were uſed.

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* Scheele. See his Eſſays, Eng. Tranſ. Eſſay XIII.

Antiphlogiſtic theory of plumbago.

The antiphlogiſtic philoſophers * conſider plumbago as a compound of iron, and the acidifiable baſe of fixed air, which they call carbone, becauſe it exiſts moſt abundantly in charcoal. The difficulty of burning or decompoſing it, is conſidered as a conſequence of the combination of its parts, which are leſs diſpoſed to unite with vital air, than either would be if alone. The ſame difficulty accounts for the large proportion of nitre required to deflagrate with it completely; a quantity required, not becauſe there is much combuſtible matter to be burned, but becauſe a long continued and elevated heat is neceſſary; by which means much of the nitre is decompoſed, and its vital air flies off, without having been employed in the combuſtion, as appears by the two thirds of the elaſtic product, which will ſupport the flame of a candle. The other facts are eaſily adapted to this theory. By detonation with nitre it affords fixed air, becauſe the combuſtible baſe is acidified by the vital air of the nitre. The arſenical acid, and metallic calces, are reduced by the abſtraction of the vital air they contained; which vital air, combining with the acidifiable baſe contained in the plumbago, converts it into the fixed air, or acid, which flies off: And, laſtly, in the diſtillation of plumbago with humid alkali, a de-

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* Acad. Par. 1785, pag. 132, et ſeq.

compo-

IRON.

compoſition of the water takes place: its inflammable air flying off; and its vital air, combining with the acidifiable baſe, as before, forms fixed air, which unites with the alkali, and renders it mild.

Reſemblance between plumbago and pyrites.

Page 417. 149.

The chief difference in the matter of fact between theſe theoriſts appears to conſiſt in the iron; which the latter conſider as a neceſſary part of the combination; by means of which they account for its difficult combuſtibility. Since plumbago does really contain iron, it may be conſidered as a compound of a ſimilar nature to the martial pyrites. Thus in the pyrites iron is united to ſulphur; which the phlogiſtian philoſophers aſſert to be a compound of vitriolic acid (or its baſe) and phlogiſton, while their opponents take the ſulphur to be a ſimple ſubſtance, capable of acidification by the addition of vital air: and ſo likewiſe plumbago is a compound of iron, united to another ſubſtance; which the phlogiſtians aſſert to be fixed air, combined with phlogiſton; at the ſame time that the other party, rejecting the inflammable principle, affirm that it is the ſimple acidifiable baſe, which will form fixed air when vital air is added to it. We ſee therefore that it is the explanation, and not the facts, which forms the object of contention.

Recapitulation of the facts relating to the ſtates of iron.

Since crude iron, then, contains the baſe of fixed air in combination, of which it may be deprived by heat with acceſs of vital air, which converts it into the acid ſtate; and ſince it again recovers that baſe by cementation with charcoal, there can be no doubt but the plumbago is afforded by the fuel, it being highly probable that iron is neceſſary to its ſeparate exiſtence. It appears alſo that the reduction of the metallic calx takes place firſt at a lower temperature; and that the combination of the baſe of fixed air follows at a greater heat. Whence, in the refining of iron, the plumbago is firſt burned, and the iron remains reduced; and, in the cementation of bar iron, the metal is converted into ſteel, with bliſters on its ſurface; which moſt probably ariſe from fixed air formed by the vital air of ſome portions of unreduced calx, uniting with the acidifiable baſe from the charcoal. And, laſtly, as iron holds this acidifiable baſe, or phlogiſticated acid, in ſolution, ſo likewiſe it may not be ſeparable from this metallic ſolvent, without carrying a portion with it; in the ſame manner as ſalts, which cryſtallize in water, always take up part of the ſolvent in the formation of their cryſtals.

Refining.

Cementation.

It would require many volumes to enumerate the leading uſes of iron. This moſt valuable of metals is applied to ſo many, and ſuch important uſes, that we cannot look round us without ſeeing its effects. When we contemplate the innumerable effects of human induſtry, and aſk ourſelves the ſimple queſtion, could this have been done without iron? there is not a ſingle inſtance which will not immediately ſhew its value. It is indeed difficult to form an idea, how civilized ſociety could exiſt without it.

Uſes of iron.

CHAP.

CHAP. VIII.

CONCERNING TIN.

TIN.
Characters of tin.

TIN is a metal of a yellowiſh-white colour, conſiderably harder than lead, ſcarcely at all ſonorous, very malleable, though not very tenacious. Wires cannot be made of it; but, under the hammer, it is extended into leaves, called tin foil, which are about one-thouſandth of an inch thick; and might eaſily be beaten to leſs than half that thickneſs, if the purpoſes of trade required it. The proceſs for making tin foil conſiſts ſimply in hammering out a number of plates of this metal, laid together upon a ſmooth block, or plate of iron. The ſmalleſt ſheets are the thinneſt. Its ſpecific gravity is leſs than that of any other malleable metal. Long before ignition, it melts at about the 410th degree of Fahrenheit's thermometer; and, by a continuance of the heat, it is ſlowly converted into a white powder by calcination. Like lead, it is brittle when heated almoſt to fuſion; and exhibits a grained or fibrous texture, if broken by the blow of a hammer; it may alſo be granulated by agitation at the time of its tranſition from the fluid to the ſolid ſtate. The calx of tin reſiſts fuſion more ſtrongly than that of any other metal; from which property, it is uſeful to form an opake white enamel, when mixed with pure glaſs in fuſion. The brightneſs of its ſurface, when ſcraped, ſoon goes off by expoſure to the air; but it is not ſubject to ruſt, or corroſion, by expoſure to the weather.

Solution of tin in vitriolic acid:

Concentrated vitriolic acid, aſſiſted by heat, diſſolves half its weight of tin, at the ſame time that vitriolic acid air eſcapes in great plenty. By the addition of water a calx of tin is precipitated. Vitriolic acid, ſlightly diluted, likewiſe acts upon this metal; but if much water be preſent, the ſolution does not take place. In the vitriolic ſolution of tin there is an actual formation, or extrication of ſulphur, which renders the fluid of a brown colour whilſt it continues heated, but ſubſides by cooling. The tin is likewiſe precipitated in the form of a white calx by a continuance of the heat, or by long ſtanding without heat. This ſolution affords needle-formed cryſtals by cooling.

— in nitrous acid.

Nitrous acid and tin combine together very rapidly, without the aſſiſtance of heat. Moſt of the metal falls down in the form of a white calx, extremely difficult of reduction; and the ſmall portion of tin which remains ſuſpended, does not afford cryſtals, but falls down, for the moſt part, upon the application of heat, to inſpiſſate the fluid. The ſtrong action of the nitrous acid upon tin produces a ſingular phenomenon, which is happily accounted for by the modern diſcoveries in chemiſtry. Mr. De Morveau * has obſerved that, in a ſolution of tin by the nitrous acid, no elaſtic fluid was diſengaged; but that volatile alkali was formed. This alkali muſt have been produced by the phlogiſticated air of that part of the nitrous acid

Singular effect.

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* Kirwan on Phlogiſton, 2d edition, p. 234.

Volatile alkali produced from nitrous acid, &c.

which was employed in affording pure air to calcine the tin. The phlogiſticated air muſt therefore have combined with inflammable air: but whether this inflammable air was afforded by a decompoſition of the water of the menſtruum, or whether it came from the phlogiſton of the tin, is a queſtion that muſt remain undetermined, until deciſive experiments have been made for the eſtabliſhment of one or the other of the two theories, which at preſent divide the chemical world.

Solution of tin in marine acid:

The marine acid diſſolves tin very readily, at the ſame time that it becomes of a darker colour, and ceaſes to emit fumes. A ſlight efferveſcence takes place with the diſengagement of a fetid inflammable gas. Marine acid ſuſpends half its weight of tin, and does not let it fall by repoſe. It affords permanent cryſtals by evaporation. If the tin contain arſenic, it remains undiſſolved at the bottom of the fluid.

— in dephlogiſticated marine acid:

Dephlogiſticated marine acid diſſolves tin very readily, and without ſenſible effervеſcence. The ſolution itſelf does not appear to differ from the foregoing.

—in aqua regia.

Aqua regia, conſiſting of two parts nitrous and one marine acid, combines with tin with effervеſcence, and the developement of much heat. In order to obtain a permanent ſolution of tin in this acid, it is neceſſary to add the metal by ſmall portions at a time; ſo that the one portion may be entirely diſſolved before the next piece is added. Aqua regia, in this manner, diſſolves half its weight of tin. The ſolution is of a reddiſh brown, and in many inſtances aſſumes the form of a concrete gelatinous ſubſtance. The addition of water ſometimes produces the concrete form in this ſolution, which is then of an opal colour, on account of the calx of tin diffuſed through its ſubſtance. The uncertainty attending theſe experiments, with the ſolution of tin in aqua regia, ſeems to depend upon the want of a ſufficient degree of accuracy in aſcertaining the ſpecific gravities of the two acids which are mixed; the quantities of each, and of the tin, together with that of the water added. It is probable that the ſpontaneous aſſumption of the oncrete ſtate depends upon water imbibed from the tmoſphere. The ſolution of tin in aqua regia is uſed y dyers to heighten the colours of cochineal, gum ac, and ſome other red tinctures, from crimſon to a right ſcarlet, in the dying of woollens.

Solution of tin in aqua regia.

M. Hermſtædt has ſucceeded in the actual acidifiation of this metal, by treating it with the marine nd nitrous acids. He diſſolves pure tin in pure maine acid, and boils this ſolution with nitrous acid diſtilled from mangancſe) until the red vapours ceaſe o appear. The fluid, which is then limpid, is exoſed to diſtillation until the whole of the marine nd nitrous acids have been diſſipated. The white emaining maſs is ſoluble in three parts of water, and the acid of tin. A red heat converts this matter into yellow tranſparent ſubſtance, neither acid nor ſoluble n water; but it regains both properties by a few eeks expoſure to the air *.

Acid of tin.

The acetous acid ſcarcely acts upon tin. The opeation of other acids upon this metal has been little quired into.

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* Journal de Phyſ. xxxv. 391. Nov. 1789.

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The fuming liquor of Libavius.

When equal parts of an amalgam of tin and mercury, and of corroſive ſublimate, are triturated together, and the mixture expoſed to diſtillation in a retort, by a very gentle heat; a colourleſs fluid firſt comes over, which is followed by a thick white fume, which becomes condenſed into a tranſparent liquor, called the fuming liquor of Libavius, on account of the copious fumes it emits when the veſſel that contains it is opened. On account of the conſiderable volatility of this liquid, it riſes, partly in the form of flowers, to the top of the bottle in which it is put; ſo that, in the courſe of ſeveral months, it becomes entirely cloſed. The compoſition and effects of this liquid were but imperfectly known until lately, when Mr. Adet made ſeveral ingenious experiments upon it. By expoſing this liquid under receivers containing dry air, over mercury, he found that the volatile fluid aroſe, and lined the veſſel with cryſtals, when water was preſent; though very few cryſtals were formed when the air was as dry as it could be made. He obſerved likewiſe, that when water was added to the fuming liquor of Libavius, it became ſolid, and ceaſed to emit fumes. A preciſe quantity of water is required to produce this effect in the moſt perfect manner. If the quantity of water be too ſmall, the liquor retains more or leſs of its diſpoſition for the fluid ſtate; and if it be too conſiderable, the fluidity of the water prevails. By ſeveral trials he found that the due proportion of water to be added to the fuming liquor of Libavius was as 7 to 22. A kind of ebullition, or eſcape of bubbles, was produced during the combination; which, on examination, was found to ariſe from the

Adet's examination of the fuming liquor of Libavius.

the eſcape of the air previouſly contained in the fluid water. He found likewiſe that this concrete ſubſtance, when rendered fluid by an increaſe of temperature, was capable of diſſolving more tin, without the diſengagement of inflammable air. After the concrete ſubſtance was ſaturated with tin, it could no longer be ſublimed, but might be made to undergo a red heat; during which time there was an eſcape of vapours, conſiſting of tin combined with the marine acid; and, after a ſtrong heat, the reſidue was a white calx of tin. It appeared therefore that the liquor of Libavius, rendered concrete by water, and ſaturated with tin, reſembles, in its properties, the common ſolution of tin in the marine acid.

Adet's examination of the fuming liquor of Libavius.

From theſe circumſtances, Mr. Adet concludes that the tin, by ſtronger affinity, combines with the aërated or dephlogiſticated marine acid of the corroſive ſublimate with which it is heated; that this combination contains no water; and that, as it abounds with a ſubſtance of ſuch extreme volatility as that aërated acid, its freezing point is very low, inſomuch that it is habitually fluid; that the addition of water, in a due proportion, alters the freezing point, and renders it concrete at a common temperature; and, laſtly, that the ſtate of the marine acid in this ſubſtance is that which is called aërated, or dephlogiſticated; which is proved as well from the experiments which aſcertain that ſtate in corroſive ſublimate, as from ſimilar experiments with the fuming liquor, which, as has been obſerved, is capable of diſſolving more tin without diſengaging inflammable air. The fuming liquor of Libavius has therefore

Page 262.

TIN.

the ſame relation to the common ſolution of tin as corroſive ſublimate has to calomel *.

The reſidue, after the diſtillation by which the fuming liquor of Libavius is produced, conſiſts of tin combined with the marine acid, calomel, and running mercury, which ſublime into the roof and neck of the retort; and at the bottom is found an amalgam of mercury and tin, covered with a ſaline combination of marine acid with tin, and ſuch other metals as the tin may have been adulterated with. Much information may be derived from the foregoing experiments of Mr. Adet reſpecting the phenomena produced when tin is diſſolved in aqua regia.

Habitudes of tin, with earths and neutral ſalts:

Earthy ſubſtances do not appear to affect this metal in the dry way. It detonates very rapidly with nitre, and becomes converted into a calx, which partly combines with the alkali. All the vitriolic ſalts are decompoſed by tin. The tin becomes calcined, and the vitriolic acid converted into ſulphur, either by the phlogiſton of the metal, according to the ancient theory; or by the ſubtraction of its vital air, according to the modern theory. This ſulphur appears to combine with the alkali, or earth of the ſalt, with which it forms an hepar that diſſolves part of the calx.

— with ſal ammoniac.

Sal ammoniac is very readily decompoſed by tin. Alkaline and inflammable air are diſengaged; and a concrete marine ſalt remains behind, which, in ſome meaſure, reſembles the fuming liquor of Libavius. The volatile alkali, or alkaline air, which eſcapes, is

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* Annales de Chimie, i. 1, &c.

diſengaged by virtue of the ſuperior affinity of the calx of tin with the marine acid, at the temperature of the experiment. The inflammable air, which likewiſe flies off, is a conſequence of the calcination of the tin; and will be derived either from the phlogiſton of the tin, or the decompoſition of the water, according to the theory which may be applied in the explanation. Notwithſtanding the facility with which this metal decompoſes ſal ammoniac, there is an inconvenience reſulting from its uſe, which depends on the great fuſibility of this metal; in conſequence of which, it cannot be intimately mixed with the ſal ammoniac, but remains at the bottom of the veſſel in the fluid ſtate; while part of the ſal ammoniac eludes its action, and is ſublimed entire.

Spontaneous decompoſition and inflammation of metallic ſalts.

If the cryſtals of the ſaline combination of copper with the nitrous acid be groſsly powdered, moiſtened, and rolled up in tin-foil, the ſalt deliqueſces, nitrous fumes are emitted, the maſs becomes hot, and ſuddenly takes fire. In this experiment * the rapid tranſition of the nitrous acid to the tin is ſuppoſed to produce or develope heat enough to ſet fire to the nitrous ſalts; but by what particular changes of capacity, has not been ſhewn.

Combination of tin with ſulphur.

If ſulphur, in powder, be added to about five times its weight of melted tin, the two ſubſtances combine, and form a black compound, which takes fire, and is much leſs eaſily fuſed than the tin itſelf. The maſs is rittle, and of a needled texture.

Aurum muſivum.

The combination of tin and ſulphur, called aurum

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* Of Dr. Higgins. Philoſ. Tranſ. lxiii. p. 137.

muſivum, is thus made: Melt twelve ounces of tin, and add to it three ounces of mercury; triturate this amalgam with ſeven ounces of ſulphur, and three of ſal ammoniac. Put the powder into a matraſs, bedded rather deep in ſand, and keep it for ſeveral hours in a gentle heat; which is afterwards to be raiſed, and continued for ſeveral hours longer. If the heat has been moderate, and not continued too long, the golden-coloured ſcaly porous maſs, called aurum muſivum, will be found at the bottom of the veſſel; but, if it has been too ſtrong, the aurum muſivum fuſes to a black maſs, of a ſtriated texture. This proceſs is thus explained: As the heat increaſes, the tin, by ſtronger affinity, ſeizes, and combines with, the marine acid of the ſal ammoniac; while the alkali of that ſalt, combining with a portion of the ſulphur, flies off in the form of an hepar. The combination of tin and marine acid ſublimes, and is found adhering to the ſides of the matraſs. The mercury, which ſerved to divide the tin, combines with part of the ſulphur, and forms cinnabar, which alſo ſublimes; and the remaining ſulphur, with the remaining tin, forms the aurum muſivum, which occupies the lower part of the veſſel. It muſt be admitted, however, that this explanation does not indicate the reaſons why ſuch an indirect and complicated proceſs ſhould be required to form a ſimple combination of tin and ſulphur.

Aurum muſivum.

Combination of tin with phoſphorus.

When tin is heated with phoſphoric acid and charcoal, the metal appears to be very little changed. A combination, however, ſeems to take place; for the phoſphorus burns on the ſurface of the metal when heated by the blow-pipe.

Tin unites with biſmuth by fuſion; and becomes harder and more brittle, in proportion to the quantity of ſemi-metal added. With nickel it forms a white brilliant maſs. It cannot eaſily be united in the direct way with arſenic, on account of the volatility of this ſemi-metal; but, by heating it with the combination of the arſenical acid and vegetable alkali, the ſalt is partly decompoſed; and the tin, combining with the acid, becomes converted into a brilliant brittle compound, of a plated texture. It is thought that all tin contains arſenic; and that the crackling noiſe which is heard upon bending pieces of tin is produced by this impurity. Cobalt unites with tin by fuſion; and forms a grained mixture, of a colour ſlightly inclining to violet. Zinc unites very well with tin, increaſing its hardneſs, and diminiſhing its ductility, in proportion as the quantity of zinc is greater. This is one of the principal additions uſed in making pewter, which conſiſts, for the moſt part, of tin. The beſt pewter does not contain above one-twentieth part of admixture, which conſiſts of zinc, copper, biſmuth, or ſuch other metallic ſubſtances as experience has ſhewn to be moſt conducive to the improvement of its hardneſs and colour. The inferior ſorts of pewter, more eſpecially thoſe uſed abroad, contain much lead, have a blueiſh colour, and are ſoft. The tin uſually met with in commerce in this country has no admixture to impair its purity, except ſuch as may accidentally elude the workmen at the mines. But the tin met with in foreign countries is ſo much debaſed by the dealers in that article, eſpecially the Dutch, that pewter and tin are conſidered

Metallic mixtures.

Pewter.

Miſtake of foreigners reſpecting Engliſh

TIN. abroad as the ſame ſubſtance. Regulus of antimony forms a very brittle, hard, mixture with tin; the ſpecific gravity of which is leſs than would have been deduced by computation from the ſpecific gravities and quantities of each, ſeparately taken. Wolfram, fuſed with twice its weight of tin, affords a brown ſpungy calx, which is ſomewhat ductile.

Native tin. Tin is ſcarcely ever found native. Native tin may be analyſed, in the moiſt way, by the application of nitrous acid, which calcines the tin, and diſſolves the other metals it may contain. One hundred and forty grains of the waſhed and dried calx are equivalent to one hundred grains of metallic tin. The metallic admixtures may be ſeparated from the nitrous acid by methods adapted to their reſpective properties; which may be eaſily gathered from what has already been obſerved in the humid analyſis of the metals before treated of.

Calciform ores of tin. The calciform ores of tin are—tin ſpar, which is generally of a whitiſh or grey colour, ſometimes greeniſh or yellowiſh, ſemi-tranſparent, and cryſtallized in a pyramidical form, or irregularly—opake brown or black tin ore, cryſtallized, and embodied in quartz, fluor, or mica, or mixed with white and yellow pyrites; theſe ores contain a mixture of iron—the reddiſh yellow, or garnet ore, which contains more of iron than of tin—and the tin ſtone, vulgarly called leadſtones, which contain ſtill leſs tin.

Tin ores containing arſenic; It was formerly ſuppoſed that tin was frequently mineralized by arſenic; but it is now admitted that the arſenic, which may be contained in tin, is afforded

and ſulphur. by the matrix. The ſcarcity of ſulphureous tin ores was likewiſe conſidered, till lately, as a very ſingular fact, on account of the facility with which that ſubſtance unites to tin: ſuch combinations, however, have ſince been found. The native aurum muſivum, from Siberia, is of this kind: and a very conſiderable vein of tin in combination with ſulphur, and an admixture of copper and iron, has been found in Cornwall*. The analyſis of tin ores in the humid way is an object of ſome difficulty; becauſe they are not acted upon effectually either by the vitriolic, nitrous, or marine acids, or by aqua regia. The method of Bergman is as follows: The ore muſt be reduced to a very ſubtile powder by levigation and elutriation. This laſt proceſs conſiſts in agitating any powder in water, which is heavy enough to ſink in that fluid. The particles will be reſiſted in their deſcent, according to the ſurfaces they oppoſe againſt the fluid. It is ſcarcely neceſſary to obſerve, that a larger body preſents a leſs ſurface to be reſiſted, than the ſame body would oppoſe if it were divided into parts. For this reaſon, when a powder, conſiſting of particles of the ſame denſity, but different magnitudes, is agitated in a ſlighter fluid, the largeſt pieces come firſt to the bottom: and hence the method of elutriation enables us to aſſort the various particles of a powder according o their magnitudes, by firſt agitating the fluid, and ucceſſively decanting it into different veſſels. Thus, or example, if the water be decanted five ſeconds after he agitation, it will leave a powder behind it; if it

Proceſs of elutriation deſcribed and explained.

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* See Magellan's Cronſtedt, p. 637. The contents of one pecimen were 30 parts ſulphur, 41 tin, 43 copper, 2 iron, and ſtony matrix.

be again decanted, at the end of five ſeconds more, the ſecond veſſel will contain a much finer powder than the foregoing; and, by a third decantation, a ſtill more ſubtile powder will be obtained. This is the method applied in the preparation of the white calx of tin, called putty, and uſed for poliſhing fine metallic ſpeculums, and the object lenſes of teleſcopes; and in this way the tin ore to be analyſed, may be reduced to a very ſubtile powder, by levigating and again waſhing the coarſe reſidue which ſubſides in the firſt veſſel. It may be obſerved, that the ſucceſſive decantations are unneceſſary where the very fineſt powder only is wanting; becauſe this may be as well obtained by ſuffering the water to ſtand a ſufficient time before it is decanted off at firſt. To the very ſubtile powder of tin ore, thus afforded, a quantity of concentrated vitriolic acid muſt be added, and kept in a ſtrong digeſting heat for ſeveral hours. A ſmall portion of concentrated marine acid muſt be poured into this when cold. A ſtrong effervеſcence takes place with conſiderable heat and the eſcape of marine acid air, which has been deprived of its water by the vitriolic acid. After the expiration of an hour or two, ſome water muſt be added, and the clear liquor decanted. The ſame operation muſt be repeated with the reſiduum, until the acids can diſſolve no more: and nothing will then remain but the ſtony matrix. The ſolution, when precipitated by means of mild alkali, will afford 100 grains of metallic tin for each 132 grains of precipitate, when waſhed and dried. If the precipitate do not conſiſt of pure tin, but contain copper or iron, it muſt be calcined for an hour

Putty.

Analyſis of tin ores, in the humid way:

in a red heat; then digeſted in nitrous acid, which will take up the copper; and afterwards in marine acid, which will diſſolve the iron.

— in the dry way.

In the dry way, after pulverization, and ſeparation of the ſtony matter by waſhing, the tin ores may be haſtily fuſed with twice their weight of a mixture of pitch and calcined borax, in a crucible lined with charcoal, and covered; or the ore may be mixed with twice its weight of tartar, one part of black flux, and half a part of reſin. This mixture being then divided into three parts, each part muſt be ſucceſſively projected into a crucible ignited to whiteneſs, which muſt be immediately covered as ſoon as the portion thrown in ceaſes to flame.

Reduction of tin in the large way.

The operation of reducing tin ores in the large way, is conducted upon ſimilar principles. When impure, they are cleanſed from foreign admixtures, by ſorting, pounding, and waſhing. A ſlight previous roaſting renders the ſtony parts more friable; and, when arſenic is contained in the matrix, it is driven off by a ſtrong heat, continued for a ſhort time; the ore being frequently ſtirred, to prevent its running together by fuſion. In the ſmelting of the ore, care is taken to add a larger quantity of fuel than is uſual in the reviving of other metals; and to avoid a greater heat than is neceſſary to reduce the ore, in order that the loſs by calcination may be prevented as much as poſſible.

Countries which afford tin.

Tin is a metal which, as far as our preſent information extends, is not very much diffuſed. It is found in Bohemia and Saxony, and on the iſland of Malacca in the Eaſt-Indies. But the largeſt quantities, TIN.

ties, at leaſt for the European conſumption, are found in England; particularly in the county of Cornwall. This iſland has been famous for its tin mines from the remoteſt periods of hiſtory; and would not, probably, have been frequented by the ancient Phœnician navigators, if they had not been attracted hither by the great plenty of tin with which it abounds. Several etymologiſts have endeavoured to ſhew that the name of Britain is derived from a word common to the Syrian and Chaldean languages, denoting tin; but on this no great ſtreſs can be laid.

Uſes.

The uſes of tin are very numerous, and ſo well known, that they ſcarcely need be pointed out. Several of them have already been mentioned. The tinning of iron and copper, the ſilvering of looking-glaſſes, and the fabrication of a great variety of veſſels and utenſils for domeſtic and other uſes, are among the advantages derived from this metal.

CHAP. IX.

CONCERNING BISMUTH.

BISMUTH.

Characters of biſmuth.

BISMUTH is a ſemi-metal, of a yellowiſh or reddiſh-white colour, little ſubject to change n the air. It is ſomewhat harder than lead, and is carcely, if at all, malleable; being eaſily broken, and ven reduced to powder by the hammer. The interal face, or place of fracture, exhibits large ſhining lates, diſpoſed in a variety of poſitions: thin pieces re conſiderably ſonorous. At a temperature not xceeding the 460th degree of Fahrenheit it melts; nd its ſurface becomes covered with a greeniſh, rey, or brown calx. A ſtronger heat ignites it, nd cauſes it to burn with a ſmall blue flame; at the ame time that a yellowiſh calx, known by the name f flowers of biſmuth, is driven up. This calx apears to riſe in conſequence of the combuſtion; or it is very fixed, and runs into a greeniſh glaſs vhen expoſed to heat alone. Biſmuth, urged by a trong heat, in a cloſed veſſel, ſublimes entire. This emi-metal cryſtallizes very diſtinctly, when gradually ooled.

Action of vitriolic acid.

The vitriolic acid has a ſlight action upon biſmuth, vhen it is concentrated, and boiling. Vitriolic acid ir is exhaled, and part of the biſmuth is converted nto a white calx. A ſmall portion combines with the itriolic acid, and affords a deliqueſcent ſalt, in the orm of ſmall needles.

BISMUTH.

Solution in nitrous acid.

The nitrous acid attacks biſmuth with the greateſt rapidity and violence; at the ſame time that much heat is extricated, and a large quantity of nitrous air eſcapes. The ſolution, when ſaturated, affords cryſtals as it cools: the ſalt detonates weakly, and leaves a yellow calx behind, which effloreſces in the air. Upon diſſolving this ſalt in water, it renders that fluid of a milky white, and lets fall a calx of the ſame colour.

White calx, or magiſtery of biſmuth.

The nitrous ſolution of biſmuth exhibits the ſame property when diluted with water; moſt of the metal falling down in the form of a white calx, called magiſtery of biſmuth. This precipitation of the nitrous ſolution, by the addition of water, is the criterion by which biſmuth is diſtinguiſhed from all other metals. The magiſtery, or calx, is a very white and ſubtile powder, when prepared by the addition of a large quantity of water: it is uſed as a paint for the complexion, and is thought gradually to impair the ſkin. The liberal uſe of any paint for the ſkin ſeems, indeed, likely to do this; but there is reaſon to ſuſpect, from the reſemblance between the general properties of lead and biſmuth, that the calx of this ſemi-metal may be attended with noxious effects ſimilar to thoſe which the calces of lead are known to produce.

Solution in marine acid.

The marine acid does not readily act upon biſmuth. It is neceſſary that the acid ſhould be concentrated, and kept a long time in digeſtion upon it; or that it ſhould be diſtilled from the ſemi-metal. The reſidue, when waſhed with water, affords a ſaline combination, which does not eaſily cryſtallize, but may be ſublimed in the form of a ſoft fuſible ſalt, called butter of biſmuth. The marine ſolution of biſmuth likewiſe affords a precipitate of calx by the addition of water. Marine acid ſeizes the calx of biſmuth, when added to its ſolution in nitrous acid; and forms a compound of ſparing ſolubility, which falls to the bottom. Alkalis likewiſe precipitate its calx; but not of ſo beautiful a white colour as that afforded by the affuſion of pure water.

Habitudes of biſmuth with earths, ſalts, ſulphur:

The effects of earths and alkalis upon biſmuth, in the dry way, have been little attended to. Nitre calcines it, with ſcarcely any perceptible detonation. Sal ammoniac is not decompoſed by biſmuth in the metallic ſtate, though its calx readily combines with the marine acid of that ſalt, and diſengages the volatile alkali. Sulphur unites with biſmuth by fuſion, and forms a blueiſh grey brilliant maſs, of a needle-formed texture.

— and metallic ſubſtances.

This ſemi-metal unites with moſt metallic ſubſtances; and renders them, in general, more fuſible. When calcined with the imperfect metals, its glaſs diſſolves them, and produces the ſame effect as lead in cupellation; in which proceſs, it is even ſaid to be preferable to lead.

Uſes.

Biſmuth is uſed in the compoſitions of pewter, in the fabrication of printers types, and in various other metallic mixtures.

Native biſmuth and its ores.

It is ſometimes found native, and may be analyſed, in the humid way, by ſolution in nitrous acid, and precipitation, by the addition of water; which throws down 113 grains of calx for every 100 of metallic biſmuth. It is likewiſe found in the calciform ſtate;

and mineralized by ſulphur, of a grey colour, reſembling galena, but heavier. Theſe ores may alſo be analyſed by nitrous acid, like the foregoing.

Reduction of biſmuth ores.

Biſmuth is eaſily ſeparable, in the dry way, from its ores, on account of its great fuſibility. It is uſual, in the proceſſes at large, to throw the biſmuth ore into a fire of wood; beneath which a hole is made in the ground to receive the metal, and defend it from calcination. The ſame proceſs may be imitated in the ſmall way, in the examination of the ores of this metal; nothing more being neceſſary than to expoſe it to a moderate heat in a crucible, with a quantity of reducing flux; taking care, at the ſame time, to perform the operation as ſpeedily as poſſible, that the biſmuth may be neither calcined nor volatilized.

CHAP. X.

CONCERNING NICKEL.

NICKEL. Characters.

NICKEL is a reddiſh white metallic ſubſtance, of great hardneſs, and of an uniform texture; very difficult to be purified, and always magnetical, whence it has been ſuppoſed to contain iron in its pureſt ſtate. It is malleable, and is ſcarcely more fuſible than pure iron. Its calces are of a green colour.

Treatment of the ores of nickel.

This metallic ſubſtance has not been applied to any uſe: and the chief attention of thoſe chemiſts who have examined it has been directed to obtain it in a ſtate of purity; which, however, has not yet been accompliſhed. It is found either native or calciform; but moſt commonly mineralized in combination with arſenic, ſulphur, cobalt, and iron, in the ore, called kupfer nickel, or falſe copper. This is of a reddiſh yellow, or coppery colour; of a texture either uniform, granular, or ſcaly; bright in its fracture, and almoſt always covered with a green effloreſcence of calx. Moſt of the ſulphur and arſenic may be driven off by long-continued roaſting, and the occaſional addition of charcoal, which prevents the arſenic from being rendered more fixed by calcination; and the green calx which remains may be fuſed by the ſtrongeſt heat of a ſmith's forge, together with two or three times its weight of black flux. The regulus thus

obtained

obtained is of a reddiſh white colour, and brittle; but is very far from being pure. Repeated calcinations for many hours, and reductions, ſcarcely deprive the regulus of iron; and it is ſtill highly magnetic, when purified to ſuch a degree as to poſſeſs conſiderable malleability. Combination with ſulphur, with liver of ſulphur, detonation with nitre, and ſolution in the volatile alkali and vitriolic acid, did not deprive it of its magnetiſm.

Pureſt regulus of nickel.

When the regulus *, obtained by ſcorification and reduction, was combined with ſulphur, and reduced again after the diſſipation of the ſulphur by ſtrong heat, and the addition of charcoal, to promote the volatility of the arſenical contents; and this proceſs was three times repeated; the reduced metal was ſo infuſible, as not to run into a maſs by the ſtrongeſt heat of a ſmith's forge, continued for three quarters of an hour. Its colour was then whitiſh, mixed with a glittering kind of red; it was ſtrongly magnetical; of a ſpecific gravity of 8.66; and a globule of one line in diameter was extended by the hammer into a plate of upwards of three lines in diameter: ſo that it is, properly ſpeaking, an entire metal, and not a ſemi-metal. It afforded a blue ſolution with the volatile alkali; and in nitrous acid its ſolution was of a full green.

— Is an entire metal.

Action of vitriolic acid.

Concentrated vitriolic acid acts upon the regulus of nickel, and corrodes it. The reſidue, after diſtillation of the acid, is a greyiſh powder; part of which is in the ſaline ſtate, and affords green cryſtals by ſolution in water and evaporation.

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* Bergman on Nickel, in vol. ii. of his Eſſays.

The

NICKEL.

The nitrous ſolution of this metal affords ſaline cryſtals. Alkalis precipitate it, and rediſſolve the precipitate. Nitre detonates with nickel in the dry way. Sulphur readily combines with it by fuſion, as does likewiſe arſenic; and both adhere very pertinaciouſly to it, as has been already ſhewn.

Whether nickel be truly a peculiar metal.

Nickel has been thought to be a modification of iron. This concluſion is grounded chiefly on its magnetiſm, and the conſideration of the very remarkable and different properties iron is known to be capable of aſſuming, in its ſeveral ſtates. Others have ſuppoſed it to be an alloy of copper with various metallic admixtures. The blue colour it affords with volatile alkali, is the chief circumſtance which gave riſe to this opinion. But it has been very properly obſerved *, that many of the known metals would ſcarcely have endured more ſevere trials than this ſubſtance has undergone, without ſhewing indications, at leaſt as ſtrong, againſt the ſuppoſition of their being diſtinct bodies, as any afforded by nickel; and conſequently, that ſo long as no one is able to produce this metal from pure iron or copper, and to explain in an intelligible way the proceſs by which it can be generated, we muſt continue to regard it as a peculiar ſubſtance, poſſeſſing diſtinct properties. The general opinions of chemiſts concur in admitting the force of this reaſoning.

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* Bergman, ii. 264.

CHAP. XI.

CONCERNING ARSENIC.

ARSENIC. Characters.

ARSENIC in the metallic ſtate, or the regulus of arſenic, is of a bright yellowiſh white colour, ſubject to tarniſh, and grow black, by expoſure to air. It is brittle, and when broken exhibits a laminated texture. In cloſe veſſels it ſublimes entire; but burns with a ſmall flame, if reſpirable air be preſent.

White calx of arſenic:

The arſenic met with in commerce has the form of a white calx. It is brought chiefly from the cobalt works in Saxony, where zaffre is made. Cobalt ores contain much arſenic, which is driven off by long torrefaction. The ore is thrown into a furnace reſembling a baker's oven, with a flue, or horizontal chimney, nearly two hundred yards long; into which the fumes paſs, and are condenſed into a greyiſh or blackiſh powder. This is refined by a ſecond ſublimation in cloſe veſſels, with a little pot-aſh, to detain the impurities. As the heat is conſiderable, it melts the ſublimed flowers into thoſe cryſtalline maſſes which are met with in commerce.

— is in a ſaline ſtate.

The calx of arſenic is ſo far in the ſaline ſtate, as to be ſoluble in about eighty times its weight of water, at the temperature of 60°, or in fifteen times its weight of boiling water.

Regulus.

The regulus may be obtained from this calx, either by quickly fuſing it together with twice its weight of ſoft ſoap, and an equal quantity of alkali, and pouring

Regulus.

it out, when fuſed, into an hot iron cone; or by mixing it in powder with oil, and expoſing it in a matraſs to a ſand heat. This proceſs is too offenſive to be made but in the open air, or where a current of air carries off the fumes. The decompoſed oil firſt riſes; and the regulus is afterwards ſublimed, in the form of a flaky metalline ſubſtance.

Action of vitriolic acid:

Vitriolic acid does not attack the regulus of arſenic, nor its calx, when cold; but, if it be boiled upon this ſemi-metal, vitriolic acid air is emitted, a ſmall quantity of ſulphur ſublimes, and the arſenic is reduced to the calciform ſtate. Boiling vitriolic acid diſſolves the calx of arſenic; but ſcarcely retains any portion of it when cold. The calx of arſenic is conſiderably leſs volatile when vitriolic acid is preſent, or mixed with it; but it is ſaid that waſhing deprives it of the acid, and reſtores its properties.

— of nitrous acid:

Nitrous acid readily attacks and calcines the regulus of arſenic: it likewiſe diſſolves the calx of this ſemi-metal, in conſiderable quantity, by the aſſiſtance of heat; and affords a cryſtallized deliqueſcent ſalt by evaporation, which does not detonate on red hot coals. The calx of arſenic is acidified by the action of nitrous acid diſtilled from it.

— of marine acid:

Boiling marine acid diſſolves the regulus, and alſo the calx of arſenic; but affects it very little when cold. This ſolution affords precipitates upon the addition of alkalis.

— of aerated acid.

The dephlogiſticated or aërated marine acid converts the calx of arſenic into arſenical acid.

The calx of arſenic acts, in many inſtances, like an acid. It decompoſes nitre by diſtillation; the nitrous acid flying off, and the arſenical ſalt of Macquer remaining behind. In this proceſs, the nitrous acid appears to acidify the calx. Quadrangular nitre is affected in the ſame manner. When the white calx of arſenic is diſtilled with ſulphur, volatile vitriolic acid flies off, and a combination of a yellow colour, called orpiment, is produced; which appears to conſiſt of ſulphur, united to regulus of arſenic; that is to ſay, part of the ſulphur receives vital air from the calx; to which, according to the ancient ſyſtem, it communicates phlogiſton: and in this manner the ſulphur becomes converted into vitriolic acid; while the arſenical calx is reduced, and combines with the reſt of the ſulphur. The combination of ſulphur and arſenic which has been fuſed, is of a red colour; and known by the name of realgal, or realgar. Realgar appears to be leſs volatile than orpiment, or the yellow combination; for it remains at the bottom, while the other ſublimes: but in what reſpect they differ from each other has not been well aſcertained. It is not improbable but that the orpiment may contain the calx in a more reduced ſtate than the realgar. A ſtrong heat converts orpiment into realgar.

Diſtillation of calx of arſenic with ſulphur.

Orpiment and realgar.

Saline liver of ſulphur diſſolves the calx of arſenic; but more readily attacks the regulus.

Liver of ſulphur.

Watery ſolutions of fixed alkalis diſſolve the calx of arſenic; and, if they be loaded with it by means of heat, a brown tenacious maſs is produced, which acquires ſolidity, has a diſagreeable ſmell, and is called hepar of arſenic. Mineral acids precipitate part of the arſenic; but a portion of it, being acidified, adheres more tenaciouſly to the alkali. The acids occa-

Fixed alkalis.

ſion no precipitation from the ſolution of arſenic in the volatile alkali. It is not eaſy to explain what happens in this caſe, without further experiments. The ſolutions of calx of arſenic in alkalis differ much in their properties from the combination which is produced when the nitrous ſalts are decompoſed by its means. This difference is accounted for from the conſideration that it is the calx of arſenic in the firſt caſe, and the acid in the latter, which combines with the alkalis.

Combination of calx of arſenic, with alkalis:

— with metals.

A ſolution of the calx of arſenic acts upon metals in the humid way, moſt probably in conſequence of its approach to the acid ſtate.

Action of arſenical acid—

Page 213.

—on gold, platina:

—ſilver:

— mercury.

The acid of arſenic being applied to the filings of the metals, in a long-necked flaſk, to prevent its reduction, acts upon ſeveral of the metals in a digeſting heat. Gold and platina are ſcarcely acted upon. Silver is not attacked by digeſtion; but when the acid comes to be fuſed, the metal is diſſolved, and affords a colourleſs glaſs, which is nearly tranſparent; ſoluble in water, with the loſs of greateſt part of the ſilver, which ſubſides in the form of a brown powder, containing a minute portion of the acid; and reducible, like the other precipitates of ſilver, by mere heat. Mercury is not attacked by the arſenical acid, in the heat of digeſtion; but when the acid and mercury are urged in a retort, by an heat which is near melting the veſſel, part of the mercury combines with the acid, and forms a yellowiſh maſs of extremely difficult fuſion; very fixed, and inſoluble in water. Diluted nitrous and vitriolic acids have ſcarcely any effect on it, but marine acid readily diſſolves it. This ſolution, by evaporation to dryneſs, and diſtillation, affords

Action of arſenical acid on copper:

corroſive ſublimate, and the reſidue is arſenical acid: whence it follows, that the mercury in the arſenical combination muſt have been perfectly calcined. Copper is diſſolved by the arſenical acid in digeſtion, and affords a green ſolution. One part of copper filings, mixed with two of dry arſenical acid, affords a blue maſs by fuſion, at an elevated degree of heat, which is ſoluble in water; and then proves to be the ſame combination as was produced by digeſtion. The watery ſolution lets fall a light blue powdery matter, conſiſting of a combination of copper with arſenical acid.

— on iron:

Iron likewiſe is attacked by this acid during digeſtion; and the whole ſolution at laſt grows gelatinous, if the digeſtion be performed in an open veſſel. If the digeſtion be performed in a long-necked or cloſe veſſel, it does not become gelatinous; but will afterwards become ſo, if expoſed to the air. In the dry way, when one part of iron filings is diſtilled with four of acid of arſenic, the maſs makes a great effervеſcence towards the end; and, when it becomes dry, it takes fire upon increaſing the heat; arſenic and regulus of arſenic being ſublimed, and a black friable reſiduum being left at the bottom, which contains but little acid of arſenic. In this proceſs it appears that the iron, which is a metal very much diſpoſed to combuſtion or calcination, ſuddenly deprives the arſenical acid of its vital air, and reduces it to the ſtate of calx and regulus; at the ſame time that, according to the ancient hypotheſis, phlogiſton paſſes from the metal to the acid.

— on lead:

Little effect is produced upon lead by digeſtion with the arſenical acid; but the combination

Action of arſenical acid on tin:

es place by fuſion in the dry way, which affords
emi-opake glaſs. When this is boiled in diſtilled
ter, the lead falls down in the form of a white
vder, containing arſenical acid, but which does not
rd arſenic by heat, unleſs charcoal be added. Tin,
eſted with arſenical acid, grows black at firſt;
erwards becomes covered with a white powder;
, at laſt, the whole maſs becomes gelatinous. In
dry way, one part of tin filings, with two of
acid, heated in a retort, took fire when ignited:
the calx of regulus of arſenic immediately ſub-
ed, leaving a limpid ſolution of tin; which, when
lled, was of a milky colour. This, when diſſolved
liſtilled water, depoſited a white calx, which con-
ed very little acid of arſenic.

— on zinc.

inc is the only metallic ſubſtance which effer-
es when digeſted with the arſenical acid. The
grows black; and the tranſparency of the acid
leſtroyed by a quantity of black powder; which,
examination by burning on a red hot iron, proves
e regulus of arſenic. This precipitated regulus
n defends the zinc from farther ſolution. The
which eſcapes during the effervefcence is inflam-
le, holding regulus of arſenic in ſolution, which
epoſits on burning. Either of the chemical the-
s will ſerve to explain theſe effects: for the zinc
alcined by receiving the vital air of the acid;
le it is ſuppoſed to give out phlogiſton enough to
ice the acid baſis to a regulus, and to afford the
mmable air which eſcapes. Or, in the other
ry, it will be ſaid that the zinc, having a ſtrong
lency to combine with vital air, and become cal-
cined,

cined, cannot decompoſe water at a moderate temperature, unleſs an acid be preſent, to remove the coating of calx by ſolution as faſt as it is formed, which mere water cannot do. This therefore is the firſt conſequence of the mutual action of water, zinc, and the acid; namely, vital air quits the water to unite with the zinc, and inflammable air flies off at the ſame time that the acid combines with the calx of zinc. But of the two metallic baſes, which are here combined by the intermedium of vital air, the zinc has a ſtrong tendency to calcination, and the arſenic to become revived: it appears therefore, from the facts, that the zinc, attracting the vital air moſt ſtrongly, becomes ſtill more calcined, and conſequently leſs ſoluble; while the arſenic is reduced by the loſs of its vital air. Whence it muſt follow, that the metallic zinc which remains, being enveloped with calx of zinc and metallic arſenic, can no longer be acted on by the acid and water which ſtill continue undecompoſed. On this, and ſimilar occaſions, it cannot however be too often repeated to the chemical ſtudent, that theories ought to be cautiouſly followed, as of uſe in the arrangement of facts, and in directing the path to future inveſtigations; that diſcriminating phenomena ought to be earneſtly ſought after, becauſe of infinitely more value than the moſt ingenious ſpeculations; and that an attachment to ſyſtem, though it frequently gives life and energy to the exertions of genius, is in general a certain ſource of prejudices, which diſable the enquirer from purſuing the ſearch after truth, and fix his mind upon words inſtead of things.

Action of arſenical acid on zinc.

Theory.

Caution reſpecting theories.

In the dry way, when one part of the filings of zinc was mixed with two of the arſenical acid, and diſtilled, the maſs took fire, with a very bright inflammation, as ſoon as the retort became red hot. The veſſel was burſt by the exploſion; and in its neck were found regulus of arſenic, and flowers of zinc. This effect may be explained from the ſame conſiderations as were applied to the combuſtion which takes place, in like circumſtances, with iron.

Action of arſenical acid on zinc:

Page 360.

Biſmuth is acted upon by the arſenical acid in digeſtion. Water precipitates a powder from the ſolution, which conſiſts of acid of arſenic, combined with calx of biſmuth. In the dry way, biſmuth is calcined by this acid, but not diſſolved; a little arſenic being ſublimed: and, if water be added to the cooled maſs, the acid is taken up, but the calx remains. Regulus of antimony is affected nearly in the ſame manner as biſmuth, in the humid way; but, in the dry way, an inflammation takes place at the time of fuſion. By digeſtion with cobalt, the acid of arſenic aſſumed a roſe colour; but much of the cobalt remained undiſſolved. The whole maſs being diſtilled to dryneſs, and fuſed, afforded glaſs of violet colour, and ſemi-tranſparent. Nickel communicates a green colour to this acid by digeſtion; quantity of green powder, mixed with arſenic, being precipitated: the arſenic may be ſeparated by a gentle heat. In the dry way, the acid combines with nickel, and forms a yellow maſs, with grey ſtreaks upon it, reſembling a vegetation. By boiling in water, the acid is taken up, and a yellow powder

— on biſmuth;

— on antimony:

— on cobalt:

— on nickel.

left behind, conſiſting of a combination of nickel and arſenic, moſt probably in the acid ſtate: the arſenic is reduced with charcoal, but the nickel is not. Calx of mangancſe is ſcarcely acted upon by acid of arſenic; but, when the mangancſe is partly or entirely reduced, it is diſſolved in the humid way; and affords cryſtals as ſoon as the acid is nearly ſaturated. The regulus, digeſted with the arſenical acid, becomes covered with a white powder of arſenical calx. When one part of the regulus was mixed with two parts of the dry acid, and expoſed to diſtillation, the regulus was ſublimed before the heat was ſufficiently great to fuſe the acid, and conſequently no mutual action took place; but when the acid was firſt fuſed, and the regulus added ſucceſſively in ſmall lumps, inflammation took place, and calx of arſenic was ſublimed.

Action of arſenical acid on manganeſe.

Combinations of regulus of arſenic.

Regulus of arſenic is ſoluble in unctuous oils, in a boiling heat: the ſolution is black, and has the conſiſtence of ſalve when cold *. Moſt metals unite with arſenic; which moſt probably exiſts, in the reguline ſtate, in ſuch as poſſeſs the metallic brilliancy. The calx, more or leſs acidified, is common in many minerals.

Uſes of arſenic.

Arſenic is uſed in a variety of arts. It enters into metallic combinations wherein a white colour is required. Glaſs manufacturers uſe it; but its effect in

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* On arſenic and its acid, conſult Scheele's Eſſays, p. 143; Bergman's Eſſays, vol. ii.; Pelletier, in the Journal de Phyſique for 1782, &c. &c.

ARSENIC.

n the compoſition of glaſs does not ſeem to be learly explained. Orpiment and realgar are uſed as igments. Some attempts have been made to introluce it into medicine; but, as it is known to be a noſt violent poiſon, it is probable that the fear of its ad effects may long deprive ſociety of the advantages t might afford in this way.

CHAP. XII.

CONCERNING COBALT.

COBALT.

Characters of cobalt.

COBALT is a ſemi-metal, of a whitiſh grey, or ſteel colour; hard, brittle; of a dull, cloſe-grained fracture, and moderate ſpecific gravity. It is rather more difficult of fuſion than copper; does not eaſily become calcined; and its calx is of ſo deep a blue colour, as to appear black. The moſt remarkable and moſt valuable property of this metallic ſubſtance is, that its calx, when fuſed with borax, or with alkali and ſand, produces a blue glaſs, known by the name of ſmalt. The action of air ſoon tarniſhes it; but water has little or no effect upon it.

Combination with vitriolic acid:

Concentrated and boiling vitriolic acid, diſtilled nearly to dryneſs, combines with this ſemi-metal. Much vitriolic acid air flies off; and the cobalt is in part calcined, and in part converted into a cryſtallizable ſalt, ſoluble in water, and precipitable by lime and by alkalis in the form of a roſe-coloured powder or calx. Diluted vitriolic acid acts upon the calx of cobalt, and forms the ſame ſalt.

— with nitrous acid.

Nitrous acid diſſolves cobalt by the aſſiſtance of a moderate heat. Nitrous air is diſengaged; and the ſolution affords deliqueſcent cryſtals by evaporation, which do not detonate on ignited coals, but boil up and leave a red calx. Lime, and the alkalis, precipitate the ſolution; and, if the alkali be added in exceſs, it diſſolves the precipitate.

The

Combination with marine acid:

The marine acid has ſcarcely any action on co- lt, unleſs it be boiling; in which caſe it diſſolves a nall portion. It diſſolves the calx more readily; ith which it forms a red brown fluid, that becomes een when heated. This ſolution affords deliqueſ- nt cryſtals by evaporation.

— with aqua regia.

Sympathetic ink.

Aqua regia diſſolves cobalt more eaſily than the arine, though not ſo readily as the nitrous, acid. his ſolution is well known, as one of the moſt cele- ated ſympathetic inks afforded by chemiſtry. If it diluted with a ſufficient quantity of water to pre- nt its action upon paper, and then uſed to write ith, the letters are inviſible as ſoon as the clear lution has become dry: but, if the paper be held to e fire for a ſhort time, they appear of a fine green lour; which again diſappears by removing it, and ffering it to cool again. If the heat be continued o long after the letters appear, it will render them rmanent. This effect ſeems to be analogous to at which obtains in the marine ſolution: but none the efficient cauſes of change of colour in this, or y other chemical phenomenon, have been hitherto plained.

Acid of borax and cobalt.

The acid of borax does not act immediately on balt, in the humid way: but borax itſelf, added to her of the foregoing ſolutions, effects a decompo- ion by double affinity; the alkali uniting with the lvent acid, while the acid of borax ſeizes the cobalt, d forms a ſcarcely ſoluble compound, which falls wn.

Acid of ſugar.

The acid of ſugar precipitates cobalt from its ſolu- ns, in the form of a pale roſe-coloured powder.

Whether

COBALT.

Habitudes of cobalt:

Whether alkalis or earths combine with this metal directly, by the intervention of water, has not been determined.

— with nitre:

Cobalt does not act on neutral ſalts in general. It detonates feebly with nitre, when projected into a red hot crucible, with twice or thrice its weight of that ſalt. The metal becomes calcined by the action of the nitre; but the changes in both ſubſtances require farther examination.

— with ſal ammoniac:

Sal ammoniac is not decompoſed by cobalt.

— with ſulphur:

Sulphur does not unite with cobalt, but with difficulty. Liver of ſulphur combines more readily with it. The action of phoſphorus, or its acid, on this ſubſtance, remains to be aſcertained.

— with metallic ſubſtances.

This ſemi-metal unites by fuſion with moſt of the metals and ſemi-metals, as has before been noticed. Silver, lead, and biſmuth, do not mix with it; and zinc does not but with great difficulty.

Native cobalt and its ores.

Cobalt is found native in alloy with arſenic and iron, and of a ſteel-grained appearance when broken; or in a calciform ſtate, of a black colour, either pulverulent or indurated: or combined with arſenical acid, in the flowers of cobalt, of a red colour; or, laſtly, united to ſulphur and iron, with or without arſenic, of various ſhades of redneſs. Biſmuth, nickel, and other ſubſtances, are contained in theſe ores. They may in general be diſtinguiſhed by ſolution in aqua regia; with which, after dilution with water, they form the ſympathetic ink above deſcribed.

Humid analyſis.

The native cobalt, and its calciform or ſulphureous ores, may be examined by ſolution in aqua regia, and evaporation to dryneſs; after which, the calcined

Humid analyſis of cobalt ores.

calcined cobalt may be diſſolved by vinegar. When this calx is precipitated by mild mineral alkali, the regulus may be accounted for, by allowing one hundred grains for every hundred and ſixty grains of precipitate. The other component parts of the reſidue, not taken up by the vinegar, may be aſcertained by the methods deſcribed in the preceding chapters. The red arſenical cobalt ore, which contains arſenical acid, may be decompoſed by vitriolic acid; and the diſengaged arſenical acid will be taken up by highly-rectified ſpirit of wine; after which, the combination of vitriolic acid and cobalt may be diſſolved in water, and precipitated by mild alkali: or the ore itſelf may be diſſolved in water, ſharpened by an acid; and the calx be then precipitated by the alkali.

Analyſis in the dry way.

In the dry way, the ores of cobalt, after previous pounding, waſhing, and roaſting, may be fuſed with three times their weight of black flux, in a lined and covered crucible, by the heat of a ſmith's forge. The tinging power of cobalt ores may be aſſayed by fuſion with three parts of fixed alkali, and five of powdered flint, or glaſs. The alkali muſt be put firſt into the crucible; next, the flint; and, above all, the roaſted ore. When cobalt ores, containing biſmuth, are reduced, this ſemi-metal uſually occupies the lower part of the crucible, and may be ſeparated from it by a blow with a hammer; or at leaſt by eliquation, or melting, on account of its greater fuſibility.

Cobalt found moſt plentifully in Saxony.

Cobalt is found in ſeveral parts of Europe, but moſt plentifully in Saxony. The ore is uſually broken

into

Manufacture of zaffre and ſmalt.

into pieces about the ſize of a hen's egg, and the ſtony parts picked out. The ſorted mineral is then pounded in mills, and ſifted through wire ſieves. By waſhing in water, the lighter parts are carried off; and the remainder is calcined in a furnace reſembling an oven, wherein it is heated by the action of the reverberated flame of wood which plays upon it. In this ſituation, it is occaſionally ſtirred with long iron rakes; and emits fumes, conſiſting chiefly of arſenic, which is collected in a long horizontal chimney, built for that purpoſe. If the ore contain biſmuth, this fuſible ſemi-metal is collected at the bottom of the furnace. The cobalt, after a ſufficient torrefaction, remains in the form of a dark grey calx, called zaffre. The zaffre of commerce always contains twice or thrice its weight of powdered flints. The flint is pulverized, for this and other purpoſes, by means of previous ignition, and quenching in water, which renders it friable. Smalt is a blue glaſs, compoſed of one part of the calcined cobalt, fuſed with two of the flint powder, and one of potaſh. Powder blue, or azure, is obtained by grinding ſmalt in mills, and afterwards waſhing it in water. This laſt operation is performed in a caſk filled with water, and pierced with three openings at different heights. The water of the uppermoſt cock carries out the fineſt blue, which they call azure of the firſt fire. The larger particles fall more ſpeedily, and the azure brought out by the water of the three cocks forms the different degrees of fineneſs known under the names of azure of the firſt, ſecond, and third fires.

The

Uſes of cobalt.

The uſe of this metallic ſubſtance is confined chiefly to the production of the blue glaſs for enamels, and other purpoſes. Powder and ſtone blue, uſed by laundreſſes, is a preparation made by the Dutch from the coarſe ſmalt.

CHAP. XIII.

CONCERNING ZINC.

ZINC.

Characters of zinc.

ZINC is a ſemi-metal, of a blueiſh white colour, ſomewhat brighter than lead; of conſiderable hardneſs; and ſo malleable, as not to be broken with the hammer, though it cannot be much extended in this way. It is very eaſily extended by the rollers of the flatting mill. When broken by bending, its texture appears as if compoſed of cubical grains. On account of its imperfect malleability, it is difficult to reduce it into ſmall parts by filing or hammering: but it may be granulated, like the malleable metals, by pouring it, when fuſed, into cold water; or, if it be heated nearly to melting, it is then ſufficiently brittle to be pulverized. It melts long before ignition, at about the 700th degree of Fahrenheit's thermometer; and, ſoon after it becomes red hot, it burns with a dazzling white flame, of a blueiſh or yellowiſh tinge, and is calcined with ſuch rapidity, that it flies up in the form of white flowers, called the flowers of zinc, or philoſophical wool. Theſe are generated ſo plentifully, that the acceſs of air is ſoon intercepted; and the combuſtion ceaſes, unleſs the matter be ſtirred, and a conſiderable heat kept up. The white calx of zinc is not volatile, but is driven up merely by the force of the combuſtion. When it is again urged by a ſtrong heat, it becomes converted into a clear yellow glaſs,

glaſs. If zinc be heated in cloſed veſſels, it riſes without decompoſition. Zinc appears to be the moſt volatile of metallic ſubſtances, except the regulus of arſenic.

Solution of zinc in vitriolic acid.

The diluted vitriolic acid diſſolves zinc; at the ſame time that the temperature of the ſolvent is increaſed, and much inflammable air eſcapes: an undiſſolved reſidue is left, which conſiſts of plumbago. The theories of this ſolution, and the diſengagement of inflammable air, are perfectly ſimilar to thoſe which have been before explained in the chapter on iron. As the combination of the vitriolic acid and the calx proceeds, the temperature diminiſhes; and the vitriol of zinc, which is more ſoluble in hot than cold water, begins to ſeparate, and diſturb the tranſparence of the fluid. If more water be added, the ſalt may be obtained in fine priſmatic four-ſided cryſtals. The white vitriol, or copperas, uſually ſold, is cryſtallized haſtily, in the ſame manner as loaf ſugar, which, on that account, it reſembles in appearance: it is ſlightly effloreſcent. The white calx of zinc is ſoluble in the vitriolic acid, and forms the ſame ſalt as is afforded by zinc itſelf.

Page 296.

White vitriol.

Solution of zinc in nitrous acid:

Diluted nitrous acid combines rapidly with zinc, and produces much heat, at the ſame time that a large quantity of nitrous air flies off. The ſolution is very cauſtic, and affords cryſtals by evaporation and cooling, which ſlightly detonate upon hot coals, and leave calx behind. This ſalt is deliqueſcent.

—in marine acid.

Marine acid acts very ſtrongly upon zinc, and diſengages much inflammable air; the ſolution, when evaporated, does not afford cryſtals.

Water impregnated with fixed air diſſolves a conſiderable proportion of zinc. The other acids have not been tried.

Habitudes of zinc:

Zinc is precipitated from acids, by the ſoluble earths, and the alkalis: the latter rediſſolve the precipitate, if they be added in exceſs.

— with vitriolic ſalts:

Zinc decompoſes, or alters, the vitriolic neutral ſalts in the dry way. When fuſed with vitriolated tartar, it converts that ſalt into liver of ſulphur; the zinc at the ſame time being calcined, and partly diſſolved in the hepar. In this operation, the vital air of the acid combines with the zinc, and calcines it; at the ſame time that, according to the ancient theory, the phlogiſton of the metal combines with the acid baſe, and converts it into ſulphur. In the new theory, the tranſition of phlogiſton is conſidered as hypothetical and unneceſſary: becauſe, the metal and the ſulphur being taken to be ſimple ſubſtances, the vitriolic acid becomes ſulphur, merely by the loſs of its vital air; and the zinc becomes calcined, merely by the acquiſition of the ſame ſubſtance.

— with nitre:

When pulverized zinc is added to fuſed nitre, or projected together with that ſalt into a red hot crucible, a very violent detonation takes place; inſomuch that it is neceſſary for the operator to be careful in uſing only ſmall quantities, leſt the burning matter ſhould be thrown about. The zinc is calcined; and part of the calx combines with the alkali, with which it forms a compound, ſoluble in water.

— with common ſalt; ſal ammoniac; and alum.

Zinc decompoſes common ſalt, and alſo ſal ammoniac, by combining with the marine acid. The filings of zinc likewiſe decompoſe alum, when boiled in a ſolution of that ſalt, probably by combining with its exceſs of acid.

Habitudes of zinc with ſulphur:

Sulphur, though its action is almoſt general on metallic ſubſtances, does not combine with zinc. This property affords a ready means of purifying the ſemi-metal, by projecting ſulphur upon it, when melted in a ſhallow crucible. It has been a ſubject of remark, among chemiſts, that many of the zinc ores conſiſt of this ſemi-metal combined with ſulphur, though art has not yet diſcovered the means of effecting the ſame combination. But the difficulty is removed by the conſideration, that the ſulphur does not unite with zinc itſelf, yet it readily does with its calx, and forms a compound ſimilar to the zinc ores, called blendes; in which, for that reaſon, the zinc may be preſumed to exiſt in the calciform ſtate.

— with liver of ſulphur:

Liver of ſulphur does not combine with zinc, either in the humid or dry way.

— with metals.

Moſt of the metallic combinations of zinc have been already treated of. It forms a brittle compound with antimony; and its effects on manganeſe, wolfram, and molybdena, have not yet been aſcertained.

Native zinc and its ores.

Native zinc has been very ſeldom found. The calciform ores of zinc are the zinc ſpar, of a whitiſh grey colour, reſembling a lead ſpar; and the impure calx called calamine, which is of a white, grey, yellow, brown, or red colour, containing iron, clay, calcareous and other earths, and lead. The ore called blende, mock lead, or black jack, conſiſts of zinc mineralized with ſulphur and iron: of this there are ſeveral varieties. They are in general of a plated texture; and frequently of a quadrangular

form,

form, like galena, or potters' lead ore, though they are conſiderably leſs heavy. Theſe ores are found in various parts of Europe; and, in conſiderable plenty, in the mine counties of England.

Humid analyſis of zinc and its ores.

Native zinc may be aſſayed, in the humid way, by the mineral acids. When it is diſſolved in theſe, if there be any other metal preſent, it may be precipitated by the addition of a known quantity of zinc. The weight of calx of zinc precipitated by mild alkali from its vitriolic ſolution, will amount to 193 grains for every 100 of the metal it repreſents. The ſulphureous zinc ores muſt be carefully treated with nitrous acid; which will diſſolve the zinc, and leave the ſulphur. Extraneous metals may be precipitated, and the quantity of zinc aſcertained, as before.

Eſſay of calamines.

The eſſay of calamines is ſometimes made by pounding and mixing them with charcoal, and then heating them in a crucible covered with a copper plate. The reduced zinc riſes, and converts the copper into braſs; and, in this way, ſome judgment may be formed of its value in the operation of braſs-making. Moſt of the zinc, whether in the metallic ſtate, or in the form of an impure calx, called cadmia fornacum, is obtained in the roaſting of various kinds of ores at Ramelſburg. For this purpoſe, the anterior part of the furnace is kept cold by wetting it: by which means the volatilized zinc is condenſed, and falls into a cavity, containing charcoal duſt, which defends it from calcination.

Diſtillation of zinc.

The proceſs for obtaining zinc from its ores by diſtillation, which is practiſed in England, and ſaid to have originally been derived from the Chineſe, is performed

Diſtillation of zinc.

performed in a furnace, in the form of a circular oven; in which are placed ſix pots, each about four eet in height, and of a conical ſhape, reſembling an oil jar. Into the bottom of each pot an iron tube s inſerted, which paſſes through the floor of the urnace into a veſſel of water. Theſe pots are filled with a mixture of calamine and charcoal; and their mouths are then cloſe ſtopped with clay. The fire being then properly applied, the metallic vapour of he calamine iſſues through the iron tube, which is he only place where it can eſcape. In this way it is ondenſed in ſmall particles in the water; which are fterwards melted into ingots for ſale, under the name of ſpelter *. The ſubſtance ſold in London by the name of ſpelter, is a kind of ſoft braſs, in a granuated form, which is uſed by the braziers and others or ſoldering.

Spelter.

Uſe of zinc. Page 283.

The chief purpoſe to which zinc is applied conſiſts n the fabrication of braſs, and other gold-coloured mixtures. Its calces and ſalts have been occaſionally employed in medicine.

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[*] Watſon's Chemical Eſſays, vol. iv.

CHAP.

CHAP. XIV.

CONCERNING ANTIMONY.

ANTIMONY. Characters of antimony.

REGULUS of antimony is of a ſilvery white colour; very brittle, and of a plated or ſcaly texture. Its ſpecific gravity is moderate. Soon after ignition it melts; and, by a continuance of the heat, it becomes calcined, and riſes in white fumes, which may afterwards be volatilized a ſecond time, or fuſed into a hyacinthine glaſs, according to the management of the heat: they are called argentine flowers of regulus of antimony. In cloſed veſſels, the regulus riſes totally without decompoſition. This metallic ſubſtance is not ſubject to ruſt by expoſure to air; though its ſurface becomes tarniſhed by that means. Its calces are ſoluble in water; and, in that reſpect, reſemble the calx of arſenic, probably by an approach towards the acid ſtate.

Action of vitriolic acid on antimony.

Vitriolic acid, boiled upon the regulus of antimony, calcines the greater part, ſo as to render it inſoluble; the acid being at the ſame time decompoſed. Much vitriolic acid air eſcapes; and, towards the end, a ſmall quantity of ſulphur is ſublimed. By waſhing the reſidue in water, a vitriolic ſalt of antimony is ſeparated from the calx, which does not cryſtallize.

Nitrous acid.

Nitrous acid very readily attacks antimony in the cold. Moſt part of the metal is calcined by this action; but a portion is diſſolved, and affords deliqueſcent cryſtals, decompoſible by heat. The calx of f antimony formed by this acid, is very white, and ifficult of reduction.

Solution of antimony in marine acid:

Continued digeſtion is required for the ſolution of egulus of antimony in the marine acid. A conſide-able quantity is however at length diſſolved; which ffords very deliqueſcent cryſtals. This ſalt melts by he application of heat; and is decompoſed by diſtilled vater, in the ſame manner as the butter of antimony, rom which it does not much differ.

— in dephlogiſticated or aerated marine acid:

Dephlogiſticated or aërated marine acid diſſolves he regulus of antimony with great facility.

— in aqua regia.

Aqua regia, compoſed of ſeven parts nitrous, and ne marine acid, diſſolves it very readily; but lets all a portion of white calx as it cools. The ſolvent ower of either of the three ancient mineral acids on his ſemi-metal, appears to be increaſed by mixture with any one of the others.

Habitude of regulus of antimony with earths:

Earthy ſubſtances do not act on the regulus of antimony in the dry way. Its calx, however, enters readily into the compoſition of glaſs; to which it imparts more or leſs of an hyacinthine colour.

— with vitriolated tartar.

When fuſed with vitriolated tartar, it converts it partly into hepar, or liver of ſulphur; which diſſolves a portion of the calx of antimony: that is to ſay, the vital air of the acid calcines the regulus of antimony, while part of the acid becomes converted into ſulphur; either ſimply by the loſs of its vital air, or elſe by that loſs, together with the acquiſition of phlogiſton from the regulus.

Detonation with nitre.

Nitre detonates very readily with the regulus of antimony: when equal parts of theſe ſubſtances are projected into a red hot crucible, the reſidue of calx and alkali is known by the name of diaphoretic

ANTIMONY.

mony. When the ſaline part is waſhed out by hot water, the reſidue is called waſhed diaphoretic antimony. The water uſed in the waſhing contains a portion of the calx, ſuſpended by the alkali. This may be precipitated by the addition of an acid, and has been diſtinguiſhed by the name of ceruſe of antimony.

Diſtillation of regulus of antimony with corroſive ſublimate.

When regulus of antimony is pulverized, and accurately mixed with about twice its weight of corroſive ſublimate, a mutual action takes place with the production of heat; and, if the mixture be diſtilled with a gentle fire, a thick fluid comes over, which congeals in the receiver, or in the neck of the retort, and is called butter of antimony. The reſidue conſiſts of revived mercury, and ſome regulus and calx of antimony. In this experiment, the dephlogiſticated marine acid combines with the antimony, while the mercury is revived; as may be eaſily explained on either of the two theories of chemiſtry. If the combination of regulus of antimony and ſulphur be uſed inſtead of the regulus itſelf, the mercury will be obtained in the form of cinnabar, at a much greater heat than is required to ſublime the butter of antimony.

Butter of antimony.

Theory.

Powder of algaroth.

When butter of antimony is thrown into pure water, an abundant white precipitate, or calx, falls down, which is a violent emetic, and is known by the name of powder of algaroth.

Bezoar mineral.

Nitrous acid diſſolves the butter of antimony. The ſolution, which does not appear to differ greatly from the ſolution of the regulus in aqua regia, ſoon depoſits a portion of calx. When an equal weight of nitrous

itrous acid has been three times diſtilled to dryneſs om butter of antimony, the reſidue, after ignition, called bezoar mineral; and ſeems to be little more an a calx of the metal.

Combination of regulus of antimony with ſulphur:

Sulphur combines very readily with the regulus of ntimony, and forms a ſubſtance differing in no re-ect from the mineral, or ore, to which the name of ntimony is excluſively appropriated. One part of lphur completely mineralizes four of the regulus.

— with liver of ſulphur.

Liver of ſulphur diſſolves the regulus of antimony, nd affords an orange-coloured precipitate upon the ddition of an acid.

Crude antimony:

—its habitudes:

by heat:

Antimony, or the regulus combined with ſulphur, as a favourite object of reſearch in the experiments the alchemiſts; in conſequence of which, its pro-erties are much better known than thoſe of the pure gulus. If this ſubſtance be heated, it melts, and conſiderable portion of the ſulphur flies off, at the me time that the regulus becomes calcined, and ſes in white vapours. A gentler heat, leſs than is eceſſary to fuſe it, converts it into a grey calx: is calx contains a portion of ſulphur. If it be rged by a ſtronger heat, it melts into the form of aſs, which is more or leſs tranſparent, according the degree of calcination of the metal, and the iſſipation of the ſulphur. When it contains much lphur, the glaſs is fuſible, opake, and of a dark d colour; whence it has been called liver of anti-ony.

— with acids.

When acids are applied to crude antimony, they iſſolve the regulus, and leave the ſulphur. The itrous acid is beſt adapted to this ſolution.

Diapho-

ANTIMONY.

Diaphoretic antimony.

Diaphoretic antimony is moſt commonly and advantageouſly prepared by detonating the crude antimony with nitre inſtead of the regulus: the only difference being, that more nitre is required for the detonation; and that the reſidue contains vitriolated tartar, as well as alkali and calx.

Antimonial medicines.

There are ſeveral preparations, conſiſting of combinations of antimony with an alkali, in which the proportions of the ingredients, and the ſtate of the calx, are very different, according to the nature and management of the proceſſes. Many of theſe have been highly praiſed in medicine; at the ſame time that they have been as ſtrongly exclaimed againſt for their ill effects. Both theſe aſſertions appear to have been well founded. It is ſufficiently proved that antimonial medicines have produced the happieſt effects, and are juſtly entitled to be conſidered as very powerful remedies; but, on the other hand, it is equally certain, that their great efficacy muſt have required greater attention, in their firſt exhibition, than perhaps may have been paid; and the complicated nature of many of the proceſſes muſt have rendered it very difficult to produce ſubſtances poſſeſſing exactly the ſame properties, or proportion of component parts, at all times.

Kermes mineral.

If antimony be treated with a fixed alkali, either by fuſion and ſubſequent ſolution in boiling water, or by ſimple ebullition, a precipitate is afforded by cooling, which is called kermes mineral, formerly uſed in medicine. It is thought to conſiſt of the calx of antimony, in combination with a portion of ſulphur; but its component parts have not been accurately determined, and its properties differ according to the various mehods uſed in preparing it.

Antimonial medicines.

The antimonial preparations moſt commonly uſed at preſent are, antimonial wine, and emetic tartar. Theſe, like every other preparation of this ſemi-metal, re prepared in a variety of ways. The wine may be had by infuſing pulverized glaſs of antimony in Spaniſh white wine for ſome days, and then filtering he clear fluid through paper. A very minute porion of the calx is taken up; and this is greater or eſs, according as the wine is more or leſs acid; and perhaps, according to the temperature of the weather at the time of adminiſtering it. On this account, it s found neceſſary to give this medicine cautiouſly, nd by ſmall portions at a time, when it is intended That it ſhall act as an emetic. The emetic or antimoniated tartar of the London College is thus prepared:—Take of crude antimony and nitre equal parts, ſeparately reduced to powder; mix them, and nject them into a crucible heated to whiteneſs, that The mixture may melt after deflagration; pour it out, and reſerve the yellow maſs beneath the ſcoriæ, under the name of crocus of antimony; reduce This to a very ſubtile powder; boil it in water, and waſh the powder repeatedly in warm water, till it becomes perfectly inſipid: then take equal parts, by weight, of the waſhed crocus of antimony and of cryſals of tartar, and boil them together, in three pints of water for every pound of the mixture, during half an hour: filter the liquor; and, after due evaporation, let it by to cryſtallize.—This is the antimoniated tartar. It is a triple ſalt, conſiſting of the acid of tartar,

Emetic wine.

Antimoniated tartar.

tartar, united to vegetable alkali, and antimony partially calcined; and is conſidered as a ſafe medicine, whoſe properties and effects are more conſtant, and milder, than moſt other antimonial remedies.

Medical effects of antimony.

It has not been clearly determined on what circumſtances the medical effects of antimony depend. The ſaline preparations of mercury, and other metals, are ſuppoſed to derive their cauſticity from their tendency to become reduced to the metallic ſtate; in conſequence of which, they corrode and decompoſe other combuſtible ſubſtances: but whether this be the caſe with antimony, is doubtful. It appears neceſſary, however, that antimony ſhould be in the ſaline ſtate, in order that it may act upon the animal ſyſtem. When the regulus is made into thoſe ſmall balls or pills, which, on account of the little change they undergo in paſſing through the human body, have been called perpetual pills, its purgative action is more or leſs violent, according to the quantity of acid it meets with; and, in the preparations of this ſemi-metal, their effects ſeem likewiſe to be governed by the ſame circumſtance joined to their reſpective degrees of ſolubility. The nearly pure and inſoluble calx, produced by detonation with a large proportion of nitre, is almoſt ineffectual; whereas the more ſoluble calces or combinations are more or leſs active, according to their reſpective nature. Hence it appears to follow, that the ſimpleſt ſaline combinations are the moſt likely to produce effects conſtantly ſimilar; and that moſt of the calces and combinations, ſo highly extolled in the earlier age of chemiſtry, are attended with dangerous uncertainty in their operation.

Perpetual pills.

ANTIMONY.

Antimony combines with moſt other metallic ſubſtances, and produces mixtures whoſe properties have been attended to under their reſpective titles.

Native antimony and its regulus.

Antimony is found either native, in maſſes of the regulus, compoſed of ſhining irregular plates; or calciform, in white cryſtallized filaments; or combined with ſulphur, in the dark blueiſh or grey friable mineral, called antimony, conſiſting moſt commonly of brilliant filaments diſpoſed parallel to each other; or, laſtly, combined with ſulphur and arſenic, in an ore which greatly reſembles the foregoing, except that it is of a red or reddiſh colour.

Humid analyſis.

Native regulus of antimony, or its calx, may be aſſayed by nitrous acid, which diſſolves whatever arſenic it may contain, and only calcines the antimony. The ſulphureous antimonial ores are moſt conveniently analyſed by aqua regia, which takes up the calx, and leaves the ſulphur, which may be ſeparated by filtration. The remaining ſolvent may be examined with the uſual precipitants. In the dry way, antimony is ſeparated from its ſtony parts by fuſion in a moderate heat, nearly in the ſame manner as biſmuth; and may be reduced, by ſlowly roaſting it, till it becomes converted into a grey calx, which may be briſkly fuſed with twice its weight of black flux.

Dry way.

Page 352.

Uſes.

Antimony and its regulus are chiefly uſed in medicine, and in ſome metallic alloys, ſuch as that uſed for printers types, ſmall ſhot, &c.

CHAP. XV.

CONCERNING MANGANESE.

MANGANESE. Characters of manganeſe.

THE regulus of manganeſe is a ſemi-metal of a dull whitiſh colour when broken, but ſoon grows dark by calcination from the action of the air. It is hard, brittle, though not pulverable, and rough in its fracture; ſo difficultly fuſible, that no heat yet exhibited has cauſed it to run into maſſes of any conſiderable magnitude; and appears to be more diſpoſed to calcination than any other metallic ſubſtance, unleſs we may except wolfram. Its calces are white when imperfect; but black, or dark green, when perfect: the white are ſoluble in acids. When broken in pieces, it falls into a powder by ſpontaneous calcination; and this powder is magnetic, though the maſſes were not poſſeſſed of that property. It ſeems as if the regulus of manganeſe were capable of depriving a ſmall proportion of iron of its magnetiſm; but that the effect ceaſes as ſoon as that regulus is converted into calx. A ſtrong heat expels vital air from the calx of manganeſe.

Concentrated vitriolic acid attacks the regulus of manganeſe, but much more readily when diluted with two or three times its weight of water; at the ſame time that inflammable air is diſengaged. A black ſpongy ſubſtance remains undiſſolved, which has not been examined. The ſolution is colourleſs, and affords cryſtals by evaporation. Mild alkalis precipitate a white calx, ſoluble in acids; but pure alkalis afford a brown calx, which ſoon grows black in the air, and is ſcarcely ſoluble. The black calx of manganeſe, when old, or well made, is altogether inſoluble in acids, unleſs ſome combuſtible ſubſtance be added. It appears therefore that the metal in this ſtate is too far calcined, and requires to be reduced again in a certain degree towards the metallic ſtate, to be diſſolved. If vitriolic acid be added, and drawn off by diſtillation ſeveral times from the black calx, by an heat nearly approaching to ignition, in a glaſs veſſel; it is found that vital air is diſengaged towards the end of each proceſs, and part of the calx is diſſolved. The ſolution of the calx in acids, by the addition of combuſtible matter, is eaſily accounted for, on either of the theories of chemiſtry, by affirming that the reduction is effected by the addition of phlogiſton, or the ſubtraction of vital air from the calx by means of the combuſtible ſubſtance. The phlogiſtic theory appears however to be deficient, in explaining the ſolution by mere vitriolic acid, at an elevated temperature *, on account of the abſence of phlogiſton; but the new theory ſimply aſſerts the facts, that the calx loſes vital air in conſequence of the elevated temperature, and is rendered ſoluble in the acid.

Black calx of manganeſe.

Theory.

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* Bergman, ii. 215 (on the hypotheſis, that heat is matter; that this matter conſiſts of pure air united to phlogiſton; and that manganeſe decompoſes the heat), derives the phlogiſton required for the ſolution, as well as the vital air which flies off, from this decompoſition. Theſe poſitions did not appear ſufficiently grounded to enter the text.

MANGANESE.

Solution of regulus of manganeſe in nitrous acid:

Nitrous acid diſſolves the regulus of manganeſe with effervescence, and the eſcape of nitrous air. A ſpongy, black, and friable matter remains, whoſe properties reſemble molybdena. The ſolution does not afford cryſtals. The perfect calx is not ſoluble in pale nitrous acid, unleſs ſome combuſtible matter be added.

— in marine acid.

The regulus is diſſolved in the uſual manner by marine acid. The black calx is likewiſe ſoluble; but adheres ſo weakly to the acid, as to be ſeparated even by the mere addition of water: but, if this ſolution be expoſed to a digeſting heat for ſome hours, an inteſtine motion, like an effervescence, takes place; the ſmell of dephlogiſticated or aërated acid is perceived; and the combination becomes more perfect, ſo as not to afford a precipitate, unleſs an alkali be added. Marine acid diſſolves the black calx alſo, by the addition of a combuſtible ſubſtance. Mercury, and even gold, will effect this combination. The ſolution of manganeſe in marine acid ſcarcely affords cryſtals, but a deliqueſcent ſaline maſs by evaporation, which is ſoluble in ardent ſpirit.

Explanation.

Page 176—180.

In the permanent ſolution of black calx of manganeſe by marine acid, it is ſeen that the acid itſelf muſt communicate the property to the calx, on which its ſolubility depends; that is to ſay, it muſt either afford phlogiſton, or abſorb vital air: and accordingly, the red vapours which eſcape are diſtinguiſhed by the name of dephlogiſticated, or aërated, marine acid, according to the theory which may be adopted by the ſpeaker.

Other

Other acids likewiſe diſſolve this metallic ſubſtance. The fluor acid, and alſo the phoſphoric acid, form compounds of difficult ſolubility, which envelope and defend it from their farther action in a ſhort time.

Combinations of calx of manganeſe in the dry way.

In the dry way, the calx of manganeſe combines with ſuch earths and ſaline ſubſtances as are capable of undergoing fuſion in a ſtrong heat. Theſe experiments are moſt advantageouſly performed by the blow-pipe, on ſmall quantities of matter; becauſe, in this way, the whole of the phenomena are clearly ſeen. The moſt remarkable property of the ſolutions is, that a due proportion of combuſtible matter renders them colourleſs; for which reaſon, the calx of manganeſe is uſed by the glaſs manufacturers, to deſtroy the colours of glaſs. If a globule of microcoſmic ſalt be fuſed by the blow-pipe upon charcoal, and a ſmall portion of the black calx of manganeſe be added, the colour will be of a blueiſh red; or of a deep red, if the quantity of calx be greater. If the fuſion be continued by the interior blue flame, the colour at length diſappears; but may be eaſily revived again, by ſoftening the globule with the exterior flame. A ſmall particle of nitre inſtantly reſtores the red colour; but inflammable matter, or vitriolic ſalts, contribute to diſcharge it. If the globule, after being deprived of all colour, be fuſed in the ſilver ſpoon, it recovers its redneſs; and the colour is not diſcharged by any management of the fuſion, unleſs ſome inflammable matter be added.

Page 209.

Page 44.

Changes of colour.

Explanation.

Theſe remarkable changes of colour, which may be repeatedly produced, depend evidently on the preſence or abſence of combuſtible matter; or, which amounts

to

Explanation of the changes of colour in glaſſes which contain manganeſe.

to the ſame thing, on the degree of calcination of the manganeſe which is held in ſolution. When the highly calcined or black manganeſe is firſt added, it produces a coloured globule; if inflammable matter be added, the calx is partly reduced, and forms a colourleſs combination. Nitre reſtores the colour by its well-known property of calcining metals. When the fuſion is performed by the interior flame, the globule may be conſidered as if heated in a cloſe veſſel, in contact with charcoal; becauſe the ſurrounding flame prevents the acceſs of air: a revival of the calx therefore enſues, and the colour vaniſhes. But when the external flame is uſed, its apex, or point only, touches the globule; and the ſurrounding air promotes or maintains the calcination more effectually than the charcoal can produce the contrary effect: the conſequence therefore is, that the colour again appears. Vitriolic ſalts ſeem to forward the action of the charcoal, which converts them into ſulphur; and the colour remains fixed in the ſpoon, becauſe there is no combuſtible ſubſtance preſent, which is ſufficiently ſo to promote the revival of the calx. It is evident that both the theories of chemiſtry are applicable to theſe facts, whether the charcoal revives the calx by phlogiſticating it, or by depriving it of its vital air; or whether the calcination by the apex of the flame be effected by the diſſipation of phlogiſton, or by the abſorption of vital air from the atmoſphere.

Theories.

Nearly ſimilar changes are produced when the calx is fuſed with borax, or an alkali.

Combination with ſulphur.

Regulus of manganeſe does not appear to combine with ſulphur; but eight parts of the calx combine with three of ſulphur, and produce a yellowiſh green maſs, which is acted upon by acids; the metal being diſſolved with efferveſcence, and the diſengagement of hepatic air. The remaining ſulphur may be collected on a filter.

Metallic combinations of manganeſe.

This ſemi-metal melts readily with moſt of the other metals, but rejects mercury. Gold and iron are rendered more fuſible by a due addition of manganeſe; and the latter metal is rendered more ductile. Copper becomes leſs fuſible, and is rendered whiter, but of a colour ſubject to tarniſh*.

Native manganeſe and its ores.

Regulus of manganeſe has been found native among the powdery or calciform ore of this metallic ſubſtance. Its properties, in this ſtate, perfectly reſemble the regulus produced by art. Manganeſe appears to exiſt in the calcined ſtate in all its ores; though contaminated with admixtures of earths, or other metallic matters. They are, white, red, brown, or black; either pulverulent, indurated, or cryſtallized. Vegetable aſhes likewiſe afford indications of manganeſe.

Humid analyſis.

To analyſe the ores of manganeſe in the humid way, they muſt be reduced to a ſubtile powder, and immerſed in a mineral acid, with a piece of ſugar to aſſiſt the ſolution. If nitrous acid be repeatedly abſtracted to ignition from the ore, the iron it contains will be rendered nearly inſoluble from calcination; and the manganeſe may be taken up by ſtrong concentrated vinegar, or diluted nitrous acid. This, when precipitated by mild mineral alkali, affords 180 grains of precipitate for every 100 grains of regulus: or if the metals be precipitated from ſuperabundant nitrous acid, by Pruſſian alkali, the manganeſe will be totally diſſolved by pure water, while the iron remains behind.

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* Annales de Chimie, i. 303.

Spontaneous inflammation of black wadd.

The ore of manganeſe, which is known in Derbyſhire by the name of black wadd, is remarkable for its ſpontaneous inflammation with oil. It is of a dark brown colour, of a friable earthy appearance, partly in powder, and partly in lumps. If half a pound of this be dried before a fire, and afterwards ſuffered to cool for about an hour; and it be then looſely mixed or kneaded with two ounces of linſeed oil; the whole, in ſomething more than half an hour, becomes gradually hot, and at length burſts into flame. This effect wants explanation. It ſeems, in ſome meaſure, to reſemble the inflammation of oils by the nitrous acid. Page 165.

Reduction of manganeſe.

The preſence of manganeſe may be aſcertained in the dry way, by the blow-pipe, from the ſingular changes of colour already deſcribed, when fuſed with microcoſmic ſalt, or borax. The reduction of the ore is effected by mixing it with pitch, making it into a ball, and putting it into a crucible lined with powdered charcoal, one tenth of an inch thick at the ſides, and one quarter of an inch thick at the bottom; then filling the empty ſpaces with powdered charcoal, and luting on a cover. This muſt be expoſed to the ſtrongeſt heat of a forge, or furnace, for an hour, or more. As the calx of manganeſe is ſtrongly diſpoſed to vitrification, fluxes rather impede than forward the reduction. The reduced globules of

MANGANESE.

Speedy calcination.

aneſe are uſually enveloped with a vitrified cruſt, hich either partly, or completely, defends them from e action of the air; but, when they are broken, ey loſe their metallic brilliancy and conſiſtence in a ry ſhort ſpace of time.

Uſes of manganeſe.

Page 176.

Manganeſe has hitherto been uſed chiefly by glaſskers and potters; but the important diſcoveries of e uſes of dephlogiſticated or aërated marine acid ll, no doubt, extend its utility to ſeveral other mafactories *.

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* On manganeſe, conſult Scheele, 67—142; Bergman, ii. 1—225; the Memoirs of Pelletier, Berthollet, &c.; and the ſtracts by Elementary Writers on Mineralogy.

CHAP. XVI.

CONCERNING WOLFRAM.

WOLFRAM.
Page 216.

TUNGSTEN and wolfram have already bee treated of in the ſection on acids; and th combinations of metals with the regulus of wolfran have been occaſionally mentioned under their reſpec tive heads. Little elſe remains therefore to be ſai of this metallic ſubſtance, than to ſpecify its genera characters.

Characters and habitudes of the calx and regulus of wolfram.

The yellow matter, or calx of wolfram, turns blu by expoſure to light; and more intenſely, if to th light of the ſun. By a ſtrong heat in a covered cru cible, it becomes of a blueiſh black colour, with lo of weight; which it recovers, together with its orig nal yellow colour, by calcination, with acceſs of ai Theſe changes to the blue colour appear therefor to be partial reductions *. One hundred grains c the yellow calx, or acid, being put into a crucib with charcoal powder, well covered, and expoſed t a ſtrong heat, became converted into a button of dark brown colour, and friable, with a diminution c forty grains of the original weight. Its ſpecific gr vity was 17.6; and, upon examination with a glaſ a congeries of metallic globules was ſeen, ſome c them of the ſize of a pin's head; which, when brok exhibited a fracture reſembling ſteel. Part of this ma

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* De Luyarts on Wolfram, page 58.

Habitudes:

ing calcined, became yellow as at firſt, and gained enty-four per cent. in weight. It was not ſoluble vitriolic or marine acid; but the nitrous acid, and ua regia, converted it again into the yellow calx. ne yellow calx itſelf could not be vitrified. Acetous id converted the yellow colour to a blue.

—with ſulphur.

When equal parts of ſulphur and the yellow calx ere urged by a ſtrong heat, a blue friable maſs re- ained, weighing leſs than one-fourth of the whole.

CHAP.

CHAP. XVII.

CONCERNING MOLYBDENA.

MOLYBDENA.

Characters of regulus of molybdena.

MOLYBDENA, like manganeſe and wolfram, has not been reduced into maſſes of any conſiderable magnitude; but has been obtained only in ſmall ſeparate globules, in a blackiſh brilliant maſs. It has been revived by a proceſs ſimilar to that by which regulus of manganeſe is obtained; but it requires a moſt extreme degree of heat for that purpoſe. The globules are grey, brittle, and extremely infuſible. By heat it is converted into a white calx, which riſes in brilliant needle-formed flowers, like thoſe of antimony. Nitrous acid readily calcines and acidifies the regulus. Nitre detonates with it, and the remaining alkali combines with its calx.

Habitudes with various ſubſtances. See alſo p. 215.

Detonation with nitre decompoſes the native molybdena; but ſolution in nitrous acid is the readieſt way to procure the acid of this ſubſtance. Pruſſian alkali, and alſo infuſion of galls, precipitate the acid from its ſolutions. When acid of arſenic is heated with molybdena, it converts part of the ſulphur into volatile vitriolic acid; which comes over, and combines with another portion, with which it riſes in the form of orpiment. No other acids but the nitrous and arſenical have any action on crude molybdena.

The

MOLYBDENA.

The regulus of molybdena unites with ſeveral of metals, and forms brittle or friable compounds.

Diſtinctive characters.

This mineral is ſcarce. It is diſtinguiſhable from ck lead by its more ſhining ſcaly appearance, and rks paper with a more brilliant ſtroke; and, as it embles no other ſubſtance, it does not require to aſſayed.

CHAP. XVIII.

CONCERNING URANITE, OR URANIUM.

METALLIC SUBSTANCES.

Uranite, or uranium.

THE celebrated profeſſor Klaproth has detected a new metallic ſubſtance in the mineral uſually diſtinguiſhed by the name of pech-blende, or pitch-blende, and ranged among the ores of zinc. As it is not reducible but with the moſt extreme difficulty, and then only into minute grains, it appears of little conſequence to enter into any formal deſcription of its metallic ſtate: for which reaſon, I ſhall follow the order of the profeſſor's analyſis in the preſent chapter *.

Deſcription of pitch-blende.

The pitch-blende, or ore of uranite, is found in maſſes, or elſe ſtratified with other earths or minerals in the Swediſh and Saxon mines. It conſiſts of two varieties: the firſt in maſſes of a blackiſh colour, inclining to a deep ſteel grey, of little brilliancy; its fracture is unequal and concave in the ſmalleſt parts. It is perfectly opake, conſiderably hard, and becomes convertible into a black powder by trituration. Its mean ſpecific gravity is about 7.5. The ſecond variety is uſually found in ſtrata, and is diſtinguiſhed from the former by a deeper black colour, intermixed with ſpots of red; its colour is more ſhining, and

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* Journal de Phyſique, April 1790.

approaches

METALLIC SUBSTANCES.

pproaches that of coal; it is leſs hard, and, when ulverized, it has a greeniſh tinge.

Habitudes by fire.

This mineral ſuffers no change before the blow-ipe. With mineral alkali it affords a ſpongy, ſemi-pake, grey globule. With microcoſmic ſalt it melts, nd affords a green tranſparent globule; and in both here are ſometimes ſeen ſmall globules of reduced ead. When the mineral is heated alone, in a proper eſſel, it gives out ſulphureous acid and ſulphur, with oſs of weight; but if be afterwards kept ignited for conſiderable time beneath a muffle, it gains ſome veight by calcination.

Action of acids on pitch-blende.

The vitriolic acid acts very imperfectly upon pitch-lende; but nitrous acid completely decompoſes it, olding moſt part in ſolution, while a ſmall proportion of ſulphur, and ſome ſiliceous earth, fall down. Marine acid acts but imperfectly upon it; but aqua regia diſſolves it, as well as the pure nitrous acid. This ſolution, after it had depoſited a ſmall quantity of corneous lead, afforded large tranſparent cryſtals by repoſe in the cold, which were of a faint yellowiſh green colour, and of a figure not eaſy to be aſcertained.

Precipitates.

It was remarkable, that this ſubſtance was not precipitable from its ſolvents either by iron or zinc; but volatile liver of ſulphur threw down a browniſh yellow precipitate. Nut-galls did not precipitate any thing, unleſs the ſuperabundant acid were neutralized by an alkali; and, in this caſe, the precipitate by galls was of a chocolate brown.

Precipitates.

A diſtinctive criterion of this metallic ſubſtance was, its browniſh red colour when ſeparated by Pruſſian alkali; a circumſtance indeed common alſo to copper: but this laſt metal falls down in flocks, whereas the former is uniformly ſeparated through the whole fluid. Volatile alkali uſually precipitates it of a yellow colour, more or leſs obſcure, according to the purity of the mineral, or of the alkali. The two fixed alkalis, when pure, precipitate it completely in the form of a lemon-coloured calx. Mild alkalis afford a paler calx.

Yellow calx of pitch-blende.

The yellow precipitate is very ſoluble in acids, and affords cryſtals by combination with the vitriolic and acetous acids. Phoſphoric acid affords yellowiſh irregular flocks, ſparingly ſoluble in water. Alkalis do not diſſolve the yellow matter either in the dry or humid way.

Reduction.

Various attempts were made by the diſcoverer to revive it to the reguline ſtate. He triturated it with linſeed oil to the conſiſtence of a paſte, burned the oil in a roaſting teſt, then placed the remaining black powder in a crucible lined with charcoal, and well covered, and expoſed it to a violent heat; which operated a reduction of mangane ſe in another crucible, but produced no other change in the calx of uranite than to render it ſoluble in nitrous acid, with effervescence, heat, and eſcape of nitrous air. This altered calx was then put into an aſſayer's teſt, covered with borax, and mixed with charcoal, and the lid luted on. The heat of a porcelain furnace reduced it into a coherent maſs, conſiſting of very ſmall metallic globules agglutinated together.

BOOK

BOOK II.

PARTICULAR CHEMISTRY.

SECTION IV.

OF MINERAL COMBUSTIBLE BODIES, AND THE DIAMOND.

CHAP. I.

OF MINERAL COMBUSTIBLE BODIES.

MINERAL COMBUSTIBLES. Enumeration.

THE inflammable ſubſtances found in the mineral kingdom are—1. Inflammable air, called fire-damp in the mines. 2. Hepatic air, which abounds in many hot baths, in mines, and in the neighbourhood of volcanos. 3. Naptha; a fine thin, fragrant, colourleſs oil, which iſſues out of white, yellow, or black clays in Perſia and Media. This is highly inflammable, and is not decompoſed by diſtillation. It diſſolves reſins, and the eſſential oils of thyme and lavender; but is not itſelf ſoluble either in ſpirit of

MINERAL COMBUSTIBLES.

Petroleum.

wine or æther. It is the lighteſt of all the denſe fluids; its ſpecific gravity being 0.708. 4. Petroleum, which is a yellow, reddiſh, brown, greeniſh, or blackiſh oil, found dropping from rocks, or iſſuing from the earth, in the duchy of Modena, and in various other parts of Europe and Aſia. This likewiſe is inſoluble in ſpirit of wine; and ſeems to conſiſt of naptha, thickened by expoſure to the atmoſphere. It contains a portion of the acid of amber.

Barbadoes tar.

5. Barbadoes tar, which is a viſcid, brown, or black inflammable ſubſtance, inſoluble in ſpirit of wine, and containing the acid of amber. This appears to be the mineral oil in its third ſtage of alteration.

Aſphaltum.

6. Aſphaltum is a ſmooth, hard, brittle, inflammable ſubſtance, which melts eaſily, and burns without leaving any aſhes, if it be pure. It is ſlightly and partially acted on by ſpirit of wine and æther.

Mineral tallow.

7. Mineral tallow, which is a white ſubſtance of the conſiſtence of tallow; and as greaſy, though more brittle. It was found in the ſea on the coaſts of Finland, in the year 1736; and is alſo met with in ſome rocky parts of Perſia. It is near one fifth lighter than tallow; burns with a blue flame and a ſmell of greaſe, leaving a black viſcid matter behind, which is more difficultly conſumed.

Jet.

8. Jet, which is much harder than aſphaltum; ſuſceptible of a good poliſh, and glaſſy in its fracture. It is highly electrical, fuſible in a moderate heat, and inſoluble in ſpirit of wine.

Pit coal.

9. Pit coal. Of this there are many varieties: they appear to conſiſt of petroleum, conſolidated with an earth, chiefly of the argillaceous kind.

Peat.

10. Peat is a black inflammable earth, which is of a viſcid conſiſtence

MINERAL COMBUSTIBLES.

ence when freſh, but hardens by expoſure to the air. 11. Turf conſiſts of mould, interwoven with the roots of vegetables. 12. Amber has been already treated of (198). It is inſoluble in water, and in ſpirit of wine; and no other acid but the vitriolic diſſolves it. By diſtillation it affords a ſmall portion of water, an oil of the nature of petroleum, and a peculiar acid.

Turf. Amber.

13. Sulphur is very abundant in the mineral kingdom. It has before paſſed under our obſervation, on account of its affording the vitriolic acid by combuſtion.

Sulphur.

14. Plumbago, or black lead.

Plumbago.

General obſervations on the combuſtible ſubſtances found in the mineral kingdom.

When we attend to the inflammable ſubſtances found in the earth, or in the mineral kingdom, we may perceive that very few, and moſt probably none of them, can be truly ſaid to belong to it; but have been elaborated in the bodies of animals or vegetables. From the turf that is pared from the ſurface of the earth, and owes its inflammability to the roots of vegetables which are mixed with it, we may deſcend to the peat, or black earth, of the moors; in many ſpecimens of which, vegetable remains are ſtill perceptible; though in moſt they appear to be deprived of every appearance of their organic texture, their oily and inflammable nature only remaining: and from thence the tranſition to pit-coal is eaſy. For if we reflect on the vaſt revolutions which the earth has certainly undergone through a long courſe of ages, by means of which its ſurface has been broken, diſplaced, and inverted, from the actions of floods, earthquakes, and the great convulſions of nature cauſed by volcanic eruptions, it will be no improbable inference, that the thin, though extenſive,

MINERAL COMBUSTIBLES.

General obſervations on the combuſtible matter found in the mineral kingdom.

ſtrata of pit coal, as well as the exſudations of naptha, petroleum, and their modifications, have all ariſen from the burying of extenſive woody tracts of the ſurface, ſuch as are common in all uncultivated countries. And this probability will be reduced to a certainty, when we advert to the natural hiſtory of pit coal, which is met with in all the various ſtates of transformation. Whole trees are converted into pit coal, in ſuch quantities together as to exhibit entire foreſts; in which the roots, trunks, branches, bark, and even ſpecies, are diſcernible. Coal-pits and ſlate-quarries exhibit innumerable marks of impreſſions of leaves, and other indications of their vegetable origin; and the analyſis of this combuſtible ſubſtance tends ſtill further to confirm this truth. On the other hand, if we attend to ſuch inferences as chemical theory might point out from the facts around us, we ſhall ſee how ſmall the probability is, that the mineral kingdom ſhould, after a certain limited time, contain inflammable bodies, if they were not occaſionally thrown into it, in conſequence of the operations carried on within organized ſubſtances. For all inflammable ſubſtances, tending to decompoſe the vital air of the atmoſphere, would, in proceſs of time, revert to the claſs of uninflammable bodies, if the operation of organized bodies, particularly of the vegetable kind, did not tend to diſengage the vital air again, and render bodies combuſtible, which were not ſo when they became parts of thoſe ſubſtances.

CHAP. II.

CONCERNING THE DIAMOND.

DIAMOND.
Characters, &c. of the diamond.

THE diamond is a mineral which, on ſeveral accounts, appears worthy to compoſe an order by itſelf. It is found in a ſandy earth in the hither peninſula of India, in the iſland of Borneo, and in the Brazils. The form of the diamond, when perfect, is that of an eight-ſided priſm. There are alſo cubical diamonds, which are ſuſpected to be of a different nature from the others. Diamonds are of a lamellated texture; and may be eaſily ſplit by a blow in a proper direction. The conſent of mankind has fixed an immenſe value upon this ſtone*. The inimitable qualities

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* The value of diamonds is reckoned by weight, at ſo much the carat. The carat uſed in this valuation is divided into four parts, called grains; but leſs than troy grains by one fifth: for 150 carats are equal to the troy ounce of 480 grains. Rough diamonds, without any flaw or blemiſh, are valued at two pounds ſterling the ſingle carat; and the expence of cutting amounts to $3\frac{3}{4}$ pounds the carat. The value is greatly diminiſhed if the diamond be imperfect, or of a bad figure; and it increaſes rapidly with the ſize. To find the worth of a rough diamond, its weight in carats muſt be ſquared, and multiplied by two, and the product will be pounds ſterling. A cut or finiſhed diamond is worth four times as much as one that is ſtill rough. Thoſe of the greateſt brilliancy are ſometimes valued at a higher rate; but this value has never been applied to ſtones of exceſſive magnitude. It does not appear

that

DIAMOND.

Hardneſs and brilliance of diamonds:

qualities to which this preference is attached, are its hardneſs, which is ſuch that it eaſily cuts all other ſubſtances, and takes a moſt exquiſite and laſting poliſh; and its very great refracting power, which is ſuch as to occaſion all the light to be reflected, which falls on any of its interior ſurfaces at a greater angle of incidence than 24¼ degrees. Hence its luſtre, when cut into the form of a regular ſolid, is very great. This may be eaſily underſtood, when it is conſidered that an artificial gem of glaſs does not reflect the light from its hinder ſurface, until that ſurface is inclined in an angle of 41 degrees. The diamond therefore will not only throw back all the light which an artificial gem would reflect, but likewiſe one half as much more; which, falling between the angles of 41 deg. and 24¼, would have been ſuffered to paſs through by the falſe gem. It is not ſurpriſing therefore that the effect of the diamond ſhould be ſo much greater; more eſpecially, when we attend to its extreme tranſparency, and the accuracy of its poliſh.

— ſoluble in vitriolic acid:

No ſolvent but the vitriolic acid has any effect on this gem; in which, if diamond powder be triturated, and evaporation carried on nearly to dryneſs, the acid grows black, and depoſits pellicles that burn,

— combuſtible.

and are entirely conſumed. In a heat ſomewhat greater than is required to melt ſilver, the diamond is entirely volatilized, and conſumed with a ſlight

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that any ſum exceeding one hundred and fifty thouſand pounds has been given for a diamond.

See Magellan's improved edition of Cronſtedt's Mineralogy, for a conſiderable maſs of entertaining information on this ſubject.

flame; diminiſhing common air, and leaving a ſoot behind.

Coloured diamonds.

Diamonds are of all colours: the clear tranſparent ſtones are the moſt eſteemed; and, next to them, thoſe of a deeper tinge. Whether theſe coloured ſtones be really of the ſame nature as the clear diamond, has not been aſcertained. The lapidaries reckon them to be diamonds from their hardneſs and luſtre.

BOOK II.

PARTICULAR CHEMISTRY.

SECTION V.

CONCERNING THE PRODUCTS OF THE VEGETABLE KINGDOM.

CHAP. I.

OF THE STRUCTURE AND COMPONENT PARTS OF ORGANIZED SUBSTANCES.

ORGANIZED SUBSTANCES.
General obſervations.

A VARIETY of changes takes place among the great maſs of minerals which come under our obſervation near the ſurface of the earth. Theſe, conſidered individually, appear to be effected chiefly by virtue of the chemical attractions or affinities, aſſiſted by thoſe variations of poſition and of temperature which ariſe from external cauſes; ſuch as the ſolar light, or the alterations which the capacities of other bodies undergo. But in vegetables and animals there

ORGANIZED SUBSTANCES.

The parts of organized bodies conſtitute apparatus for performing chemical operations.

is an expreſs organization of parts, which evidently appears to have been deſigned by the Supreme Intelligence for the purpoſe of uniting the powers of mechaniſm to thoſe of chemiſtry. It does not immediately coincide with our preſent intention, to take any notice of ſuch effects as are produced by the muſcular exertion of animals, or any part of their ſtructure, except ſo far as they modify the chemical proceſſes carried on within them. In this point of view, we may conſider the ſolid or conſiſtent parts of vegetables and animals as compoſing an apparatus for performing a number of chemical proceſſes with the fluids that circulate through them. It is true indeed that this whole ſeries of operations is, for the moſt part, performed with ſuch a minute ſet of veſſels; at the ſame time that the bodies applied to each other, to exerciſe their reſpective chemical attractions, ſeem in general to be reduced ſo near their firſt principles; that in the preſent ſtate of our knowledge we can ſcarcely proceed farther than to aſſert, that the effects are really produced by an application of the moſt ſublime chemiſtry: but theſe difficulties ought rather to encourage than depreſs our attempts to arrive at a more intimate knowledge of the powers of nature.

Vegetable bodies.

The organs of vegetables appear to conſiſt chiefly of tubes, adapted to imbibe fluid matter from the earth. This fluid, which is moſtly water, riſes either by the capillary attraction, by the alternate expanſions and contractions which depend on temperature, or by other means; and depoſits its impregnations during its tranſition through the veſſels of the plant.

The

ORGANIZED SUBSTANCES.

Vegetable bodies.

The action of the ſolar light, the agitation produced by winds, and the nature of the circumambient air, are of great importance in theſe proceſſes. It is known that vegetables do not thrive in vital air; that they abſorb fixed air; and that they emit vital air during the action of light, more eſpecially the ſtrong light of the ſun. That they emit plentiful exhalations of various kinds, is obvious from their ſmell; from the humidity of countries abounding with woods; as well as from the conſideration of the ſhort time that would be required to dry the leaves of vegetables, if they did not conſtantly receive a ſupply of moiſture to recruit what they muſt loſe by conſtant evaporation. We ſee therefore that plants are aſſemblages of veſſels, in which water and aërial fluids are received; and by ſucceſſive mixtures, filtrations, evaporations, or depoſitions, are either decompoſed, or form new compounds. Thus it may ariſe from the decompoſition of water itſelf, that they emit vital air; while the other principle, or inflammable air, is retained, and enters into the compoſition of their combuſtible parts. Or, if the decompoſition of water be denied, the vital air may ariſe from the abſorption of fixed air; whoſe combuſtible principle (whether it be ſuppoſed to be inflammable air, as ſome philoſophers infer; or charcoal, according to others) may be retained, and anſwer a like purpoſe; ſince both theſe ſubſtances are obtained in the inflammation of vegetables.

Page 95.

Page 185.

Animal bodies.

Animal bodies are of a much more elaborate ſtructure. In theſe there is a proviſion for mechanically dividing ſolid bodies by maſtication, which anſwers the

ORGANIZED SUBSTANCES. Animal bodies.

the ſame purpoſe as grinding, pounding, or levigation, does in our experiments; namely, that of enlarging the quantity of ſurface to be acted upon by ſolvents. The proceſs carried on in the ſtomach appears to be of the ſame kind as that which we diſtinguiſh by the name of digeſtion; and the bowels, whatever other uſes they may ſerve, evidently form an apparatus for filtering, or conveying off, the fluids; while the more ſolid parts of the aliments, which are probably of ſuch a nature as not to be rendered fluid but by an alteration which would perhaps deſtroy the texture of the machine itſelf, are rejected as uſeleſs. When this filtered fluid paſſes into the circulatory veſſels, through which it is driven with conſiderable velocity by the mechanical action of the heart, it is not only ſubjected to all thoſe changes which the chemical action of its parts is capable of producing, but is likewiſe expoſed to the air of the atmoſphere in the lungs, into which that elaſtic fluid is repeatedly admitted by the act of reſpiration. Here it undergoes a change of the ſame nature as happens to other combuſtible bodies when they combine with its vital part. This vital part becomes condenſed, and combines with ſome principle emitted from the blood; at the ſame time that it gives out a large quantity of heat, in conſequence of its own capacity for heat being diminiſhed. It has not been aſcertained whether the ſubſtance which converts the inſpired vital air into fixed air (of which a portion is expired from the lungs together with the noxious or phlogiſticated air) be inflammable air or charcoal; and it has likewiſe been doubted whether any part of the vital air is abſorbed by

Page 34.

Page 33. 92.

Page 185.

by the blood. Later experiments of Dr. Prieſtley ſhew, however, that this laſt event does actually take place *.

Secretions, or combinations of vegetable and animal ſubſtances.

It would lead us too far from our purpoſe, if we were to attempt an explanation of the little we know reſpecting the manner in which the ſecretions, or combinations, that produce the various animal and vegetable ſubſtances, are effected; or the uſes of thoſe ſubſtances in the œconomy of plants and animals. Moſt of them are very different from any of the products of the mineral kingdom. We ſhall therefore only add, that theſe organized beings are ſo contrived, that their exiſtence continues, and all their functions are performed, as long as the veſſels are ſupplied with food, or materials, to occupy the place of ſuch as are carried off by evaporation from the ſurface, or otherwiſe; and as long as no great change is made, either by violence or diſeaſe, in thoſe veſſels, or the fluids they contain. But as ſoon as the entire proceſs is interrupted in any very conſiderable degree, the chemical arrangements become altered; the temperature in land animals is changed; the minute veſſels are acted upon, and deſtroyed; life ceaſes; and the admirable ſtructure being no longer ſufficiently perfect, loſes its figure, and returns, by new combinations and decompoſitions, to the general maſs of unorganized matter, with a rapidity which is uſually greater, the more elaborate its conſtruction.

Nutrition.

Diſeaſe.

Death.

The parts of vegetable or animal ſubſtances may be obtained, for chemical examination, either by ſim-

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* Phil. Tranſ. lxxx. 106.

ple

ORGANIZED SUBSTANCES.

Various methods of ſeparating the parts of animal or vegetable ſubſtances.

ple preſſure, which empties the veſſels of their contents; by digeſtion in water, or in other fluids, which diſſolve certain parts, and often change their nature; by deſtructive diſtillation, in which the application of a ſtrong heat alters the combination of the parts, and cauſes the new products to paſs over into the receiver, in the order of their volatility; by ſpontaneous decompoſition, or fermentation, wherein the component parts take a new arrangement, and form compounds, which did not, for the moſt part, exiſt in the organized ſubſtance; or, laſtly, the judicious chemiſt will avail himſelf of all theſe ſeveral methods ſingly, or in combination. He will, according to circumſtances, ſeparate the parts of an animal or vegetable ſubſtance by preſſure, aſſiſted by heat; or by digeſtion, or boiling in various fluids added in the retort, which contains the ſubſtance under examination. He will attend particularly to the products which paſs over; whether they be permanently elaſtic, or ſubject to condenſation in the temperatures we are able to produce. In ſome caſes, he will ſuffer the ſpontaneous decompoſition to precede the application of chemical methods; and in others he will attentively mark the changes which the products of his operations undergo in the courſe of time, whether in cloſed veſſels, or expoſed to the open air. Thus it is that, in ſurveying the ample field of nature, the philoſophical chemiſt poſſeſſes numerous means of making diſcoveries, if applied with judgment and ſagacity; though the progreſs of diſcovery, ſo far from bringing us nearer the end of our purſuit, appears continually to open new ſcenes; and, by enlarging our powers of inveſtigation, never fails to point out additional objects of enquiry.

Vegetable products arranged.

In treating of the products of the vegetable kingdom, we ſhall attend rather to the proceſſes by which we obtain them, than to any arrangement ſuppoſed to exiſt among their principles. In this way, the order will conſiſt, firſt of principles not ſaline, obtained in a degree of heat not exceeding that of boiling water; ſecondly, ſaline principles, obtained by preſſure, or mere ſolution in water, or ardent ſpirit; thirdly, ſaline principles, obtained by ſtrong heat, or by the action of nitrous acid; fourthly, the products of deſtructive diſtillation; and, laſtly, the products of ſpontaneous decompoſition, or fermentation.

CHAP. II.

CONCERNING SUCH PRINCIPLES OF VEGETABLES AS DO NOT EXHIBIT SALINE PROPERTIES, AND ARE OBTAINED WITHOUT THE APPLICATION OF ANY GREATER HEAT THAN THAT OF BOILING WATER, AND WITHOUT THE ACTION OF ANY SOLVENT BUT WATER, OR ARDENT SPIRIT.

VEGETABLE PRINCIPLES.

Juices and extracts.

THOSE immediate principles of vegetables, which do not evidently exhibit ſaline properties, are called juices, when they flow out of inciſions made in the living plant, or are obtained by ſimple preſſure; and extracts, when rendered thick by evaporation of part of the water they contain. The juices of plants are purified by ſuffering their groſſer parts to ſubſide, or by filtration. In ſome caſes, the fluid is rendered clearer by ſimply heating it in a water-bath, which cauſes part to take the form of a coagulum.

Purification.

Manipulation.

Dry plants, or woods, or ſeeds, are either raſped, pounded, or ground, to ſeparate their parts, and may be macerated, boiled, or digeſted in water, or ſpirit of wine; or the inſoluble parts may be ſubjected to preſſure, to force out their fluid contents. Theſe fluids may be purified by means ſimilar to thoſe which are applied to the expreſſed juices of plants.

The

VEGETABLE PRINCIPLES.

Enumeration of ſuch principles of vegetables as are not ſaline.

The principles of plants which are not of a ſaline nature, and are obtained without deſtroying them by heat, are—1. Gum, or mucilage, which is ſoluble in water, but not in ardent ſpirit. 2. Sugar, which is oluble both in water and in ardent ſpirit. 3. Starch, which, though inſoluble in either of theſe fluids, forms paſte with water, eſpecially if heated. 4. Vegetable luten, which is neither ſoluble nor diffuſible in water r ardent ſpirit; has a tenacious conſiſtence when recently prepared; but does not imbibe water after it as once been dried. 5. Fat oils, which are inſoluble n water or ardent ſpirit, and are either fluid, or fuſible without alteration, by a moderate heat. 6. Volatile r eſſential oils, which are ſoluble in ardent ſpirit, but ot in water, and riſe totally in diſtillation. 7. Camhor, which differs from eſſential oils in being more oncrete, more volatile, and in being totally ſoluble, without alteration, in concentrated acids. 8. Reſins, hich differ from eſſential oils, in being decompoſable y heat; and from camphor, in being changed by cids. 9. The aromatic principle, or vegetable priniple of ſmell. 10. Colouring matters.

Juices or extracts.

The juices or extracts of plants, in general, contain oth gum and reſin, which may be ſeparated by their ſpective ſolvents, water and ardent ſpirit. Theſe pear to exiſt together in the plant, forming a comound of a ſoapy or ſaponaceous nature.

Gum.

Gum is a ſubſtance very well known. It is uſually anſparent, more or leſs brittle when dry, and gives hick, viſcid, and glewy conſiſtence to water in which is diſſolved. Gum is uſually obtained by wounding

Mucilage or gum.

the trunks or branches of trees, ſuch as the plum, the pear, the cherry tree, &c.; and is diſtinguiſhed by various denominations, according to the plant from which it is obtained. It is obſervable that ſaccharine fruits, when ſour and unripe, are found to contain gum, and an acid; whence the ſaccharine matter ſeems to be formed of theſe principles. This is rendered much more probable from the conſideration that gum and ſugar afford nearly the ſame products by heat, or by diſtillation with the nitrous acid, as we ſhall hereafter ſhew.

Sugar.

Sugar may be reckoned among mucilages or gums: it appears to be brought nearer to the ſaline ſtate. Ardent ſpirit diſſolves it as well as water. The peculiar taſte of this ſubſtance indicates its preſence in a number of fruits and other vegetables; but it is moſt plentifully obtained from the ſugar cane, which is cultivated in warm climates. The juice of the plant is expreſſed by paſſing it between two cylinders of iron, placed perpendicularly. This fluid, which is thick and tenacious, is boiled together with lime and alum, and is afterwards ſuffered to cryſtallize by ſtanding in a veſſel, in the bottom of which are holes imperfectly ſtopped, in order that the ſyrup may drain off. The proceſs of refining ſugar appears to be capable of conſiderable improvement. It is not clearly aſcertained what effect the lime and alum have upon the proceſs; but it is highly probable that a part of the ſugar is burned in the boiling, and converted into an acid, which combines with the lime, and would elſe impede the cryſtallization of the ſugar. The coarſe ſugar thus produced, is refined by ſubſequent ſolution in water, and boiling with a ſmall proportion of lime, together with

Manufacture of ſugar.

VEGETABLE PRINCIPLES.

Manufacture of ſugar.

with bullock's blood or eggs. Theſe fluids, which are at firſt diffuſed through the liquor, have the property of becoming concrete, as the temperature increaſes, and riſe in the form of ſkum to the ſurface of the fluid, carrying with them the impurities, and rendering it more clear and tranſparent. The filtered liquor is then either poured into moulds, in which, by a confuſed cryſtallization, it forms loaf ſugar; or elſe it is expoſed in heated rooms, where, by a gradual cryſtallization, it forms ſugar-candy.

The habitude of ſugar with water greatly reſembles that of ſalts; but it has not been aſcertained that it contains any ſalt ready formed, except a ſmall proportion of alkali. It is more inflammable than gums.

Flour, or the powder of farinaceous ſeeds.

Flour, or the pulverized ſubſtance of farinaceous ſeeds, has a ſtrong analogy to the gummy and ſaccharine mucilages. Theſe ſeeds, if moiſtened, and expoſed to a moderate or ſummer temperature, become in a great meaſure converted into ſaccharine mucilages, as happens in the proceſs of converting barley into malt.

Wheat flour waſhed in water.

Wheat flour may be taken as an example of the compoſition of theſe ſeeds, before they begin to vegetate freſh. If this be made into a paſte, and waſhed in a large quantity of water, it is ſeparated into three diſtinct ſubſtances; a mucilaginous ſaccharine matter, which is really diſſolved in the liquor, and may be ſeparated from it by evaporation; ſtarch, which is ſuſpended in the fluid, and ſubſides to the bottom by repoſe; and gluten, which remains in the hand, and is tenacious, very ductile, ſomewhat elaſtic, and of a brown grey colour. The firſt of theſe ſubſtances does not eſſentially differ from other ſaccharine muci-

Starch.

lages. The ſecond, namely the ſtarch, forms a glewy fluid by boiling in water, though it is ſcarcely, if at all, acted upon by that fluid, when cold. Its habitudes and products with the fire, or with nitrous acid, are nearly the ſame as thoſe of gum, and of ſugar. It appears to be as much more remote from the ſaline ſtate than gum, as gum is more remote from that ſtate than ſugar.

Vegetable gluten.

The vegetable gluten, though it exiſted before the waſhing in the pulverulent form, and has acquired its tenacity and adheſive qualities from the water it imbibed, is nevertheleſs totally inſoluble in that fluid. It has ſcarcely any taſte. When dry it is ſemi-tranſparent, and reſembles glue in its colour and appearance. If it be drawn out thin, when firſt obtained, it may be dried by expoſure to the air; but, if it be expoſed to warmth and moiſture while wet, it putrefies like an animal ſubſtance. The dried gluten, applied to the flame of a candle, crackles, ſwells, and burns, exactly like a feather or piece of horn. It affords the ſame products by deſtructive diſtillation as animal matters do; is not ſoluble in ardent ſpirit, oils, or ether; and is acted upon by acids and alkalis, when heated.

Fat oils.

Fat oils are obtained by preſſure from the emulſive ſeeds or kernels of vegetables: they are generally fluid in the temperature of the atmoſphere, but ſome of them have a conſiderable degree of firmneſs or ſolidity. They have a very ſmooth feel; are moſtly without ſmell or taſte; require a degree of heat much ſuperior to that of boiling water, to cauſe them to riſe in ebullition; and cannot be ſet on fire, unleſs heated to this

degree.

Fat oils:

degree. The uſe of the wick of a lamp conſiſts in bringing ſmall portions of oil to its extremity, by the capillary attraction, where they become ſucceſſively volatilized and inflamed. Oils are remarkably leſs ſonorous than water, when poured out. Fat oils, not being at all diſſipated by the heat of the atmoſphere, make a permanent greaſy ſpot when they fall on porous ſubſtances.

— decompoſed by diſtillation;

Theſe oils are decompoſed by diſtillation, and afford a ſmall quantity of water loaded with a peculiar acid, a light oil, a denſe oil, inflammable air, and fixed air. The reſidue conſiſts of a ſmall quantity of charcoal.

— habitudes with air, water, and various ſubſtances.

Fat oils, by expoſure to the air, become rancid; and exhibit a diſengaged acid, which may be waſhed off by water. When they are expoſed to the air, in a thin coat upon the ſurface of water, they become more conſiſtent, like wax, by abſorbing the vital part of the atmoſphere; the aërated or dephlogiſticated marine acid produces this change more ſpeedily. Agitation in water ſeparates a mucilage from them. They combine with magneſia, and with lime, which convert them into ſaponaceous compounds. With the pure alkalis they form common ſoap. They do not unite with the volatile alkali, but by long trituration.

Page 120.

The mineral acids unite with fat oils, and form compounds, or imperfect ſoaps. Fuming nitrous acid cauſes them to take fire, as has already been obſerved. Sulphur is ſoluble in fat oils, by a digeſting heat; and is gradually depoſited in part from them, in a cryſtalline form, by cooling.

Page 165.

Theſe ſulphureous compounds are called balſams of ſulphur.

Bitumens and amber are ſoluble in fat oils, and form varniſhes.

Volatile or eſſential oils:

Volatile or eſſential oils have uſually a ſtrong aromatic ſmell, are ſufficiently volatile to riſe with the heat of boiling water, and are in general ſoluble in ſpirit of wine. They exiſt in almoſt all fragrant vegetables; and in the various plants they are found either in the wood, the root, the bark, the leaves, the flowers, the fruits, &c. They differ very much in the degree of fluidity they poſſeſs at a common temperature, and their colours are various. They are obtained either by expreſſion, as from the peel of oranges and lemons, or by diſtillation with water.

— obtained by preſſure or by diſtillation:

Some eſſential oils, ſuch as thoſe of cinnamon, ſaſſafras, and other foreign plants, ſink to the bottom of the water, with which they come over; others float at the top. It is eaſy to diſtinguiſh the adulteration of volatile oils, either by pouring ardent ſpirit upon them, which will not diſſolve the fat oil they may be contaminated with; or if they be dropped on paper, and held to the fire, in this caſe they leave a greaſy ſpot behind. If oil of turpentine be fraudulently added to them, its ſmell betrays its preſence when treated in this manner.

— are inflammable.

Volatile oils are very inflammable. By expoſure to air, they become thick in proceſs of time, and aſſume the character of reſins.

Combinations.

They unite with difficulty to lime and alkalis. The vitriolic acid converts them into bitumens; but, if diluted, it renders them ſaponaceous, as does likewiſe the muriatic acid. Nitrous acid inflames them.

They unite very readily with ſulphur, and form balſams,

ſams. Mucilages and ſugar render them ſoluble or diffuſible in water.

Camphor.

Camphor is a peculiar vegetable ſubſtance, which reſembles volatile oil, and is in fact depoſited from ſome of the volatile oils by long ſtanding. It has been obtained in ſmall quantities by diſtillation with water from thyme, roſemary, ſage, and other fragrant plants. The camphor of commerce is obtained from a ſpecies of laurel, which grows in China and the Indian iſlands, by diſtillation of the wood and other parts of the tree with water. The camphor riſes by the heat, and is afterwards purified by a repetition of the proceſs, with the addition of about one-twelfth of its weight of lime.

Characters of camphor:

This ſubſtance is much more volatile than eſſential oils. It cannot be preſerved without loſs, but in cloſed veſſels, and even in theſe it ſublimes by the heat of ſummer. Water does not diſſolve it; but it is plentifully ſoluble in ſpirit of wine, in ether, and in concentrated acids; from all which it is ſeparated, without alteration, by the addition of water. Fixed and volatile oils diſſolve camphor, with the aſſiſtance of heat, and depoſit cryſtals in the form of a beautiful vegetation by cooling.

— its acid.

A peculiar acid is formed by diſtillation of the nitrous acid from this ſubſtance.

Reſins, how obtained.

Reſins are dried juices of plants, which are of the nature of eſſential oil. They uſually flow from wounds made in the trunks of trees for that purpoſe. Fragrant reſins have been diſtinguiſhed by the name of balſams. Almoſt all the concrete juices, diſtinguiſhed by the name of reſins, are ſoluble in ardent ſpirit. Water diſſolves none of them. They are inflammable, and burn with much ſmoke. In cloſed veſſels they do not riſe wholly by heat, like eſſential oils, but are decompoſed.

Reſinous ſubſtances.

A very conſiderable number of reſinous ſubſtances are known and uſed in the arts. Common reſin of the pine, the reſin of the fir, pitch, tar, and turpentine, are among thoſe which are ſoluble in ſpirit of wine, and are of the nature of eſſential oils. Copal, and the elaſtic ſubſtance called caoutchouc, which is the inſpiſſated juice of a tree from Africa, are uſually reckoned among reſins; though neither ſpirit of wine nor water diſſolves them. They are ſoluble however in oils, by the aſſiſtance of heat, and ſeem to be of the nature of fat oils. The juices called gum reſins are variouſly ſoluble in the different menſtruums, according to the nature and abundance of their component parts.

Principle of ſmell in vegetables.

The principle of ſmell in plants appears to be of an exceedingly ſubtile nature. It ſeems in general to reſide in the eſſential oil, and compoſes an extremely ſmall part of the weight of vegetables, as may be inferred from the loſs of fragrance ſuſtained by eſſential oils, with little or no loſs of their weight. This however does not neceſſarily ſuppoſe that the whole principle of ſmell has flown off; becauſe it may with equal probability be ſuppoſed to have entered into combination with ſome of the other principles of the ſubſtance which afforded it. Diſtillation with ſpirit of wine is uſed to extract the fragrant principle from plants. A conſiderable proportion of this matter may be obtained by diſtillation with water, in which it comes over probably diffuſed with a ſmall proportion of eſſential oil. It has been ſuppoſed to conſiſt of an elaſtic fluid of a peculiar nature.

Colouring matters:

The knowledge of the colouring matters of vegetables is of great importance to ſociety, as the art of dying depends on the application of theſe ſubſtances. Much however remains to be aſcertained concerning them. If the doctrine of Newton were incontrovertibly eſtabliſhed, that the colours of bodies depend ſolely upon the magnitude of the integrant particles of bodies, we might aſſert, without heſitation, that all the principles of bodies might be applied in theory to the production of any aſſignable colour; and we might thence infer, that the colour of plants is not produced by the diffuſion of coloured particles of any particular kind, but by the configuration of the parts taken in general. But we are not ſufficiently advanced in any part of the knowledge of nature, to reaſon with ſafety, without conſtant recurrence to the teſt of experiment. In this way we find that the chemical ſolvents, in many inſtances, deprive plants of their colour, at the ſame time that they themſelves acquire it; doubtleſs by ſolution of the colouring matter, which they again depoſit upon bodies prepared for that purpoſe. Water diſſolves the colouring matter of various ſubſtances, ſuch as logwood, madder, &c. The ſtuffs to be dyed require, in many caſes, the previous ſoaking in a ſolution of alum, vegetable alkali, or other ſalts, to prevent their giving the colour out again to water. Other colouring principles are ſoluble in oils, ſuch as alkanet; and many which are not ſoluble

— are taken up by chemical ſolvents.

Art of dying.

ſoluble in water, are taken up by that fluid, by the intervention of an alkali. The art of dying, or of fixing colouring matter upon various ſtuffs, appears to depend upon the chemical affinities of the colouring matters either with the ſtuffs themſelves, or the matters in which they are previouſly infuſed. The condition required in a good dye appears to be, that the colouring matter ſhall be precipitated on the ſtuff, and form a compound not ſoluble in the liquids to which the ſtuff will probably be expoſed. Thus, for example, printed or dyed linens or cottons ought to reſiſt the action of ſoap and alkalis; and woollens ought more particularly to withſtand the action of acids, ſuch as lemons, vinegar, &c. which may accidentally fall on them.

Lakes.

Certain colours, called lakes, are prepared by diſſolving the vegetable colouring matters, and precipitating them by the addition of ſome other ſubſtance. Thus, for example, if madder be boiled in water together with an alkali, and alum be then added, the earth of the alum will be precipitated together with the colouring matter, with which it will form an inſoluble pigment.

CHAP. III.

CONCERNING THE SALINE PRINCIPLES OF PLANTS OBTAINED BY PRESSURE, OR BY THE APPLICATION OF WATER OR ARDENT SPIRIT; PARTICULARLY THE ACIDS OF LEMONS, OF APPLES, OF NUT-GALLS, AND OF BENZOIN.

VEGETABLE SALTS.

Mineral ſalts found in vegetables.

THE ſaline principles of plants are either ſuch as are found in the mineral kingdom; namely, vitriolated tartar, Glauber's ſalt, nitre, common ſalt, and the fixed alkalis; or they are ſuch as are peculiar to this kingdom. The mineral ſalts are ſuppoſed to have entered into the veſſels of the plants which afford them, and to have remained there unaltered. The ſalts peculiar to vegetables are, for the moſt part, of an acid nature. They conſiſt of the acids of lemons and of apples, which are obtained in an impure ſtate by preſſure; the acid of nut-galls, and the acid of benzoin; the ſalts of tartar and of ſorrel, which contain a portion of alkali; and ſuch acids as are formed by diſtilling the nitrous acid from vegetable ſubſtances, which are thoſe of ſugar, camphor, cork, &c. Deſtructive diſtillation likewiſe developes or forms peculiar acids. Thoſe obtained from tartar, from mucilage or ſugar, and from wood, have only been examined.

Peculiar ſalts enumerated.

Various methods of preſerving lemon-juice:

The juice of lemons, or limes, has all the characters of an acid of conſiderable ſtrength. On account of the mucilaginous matter with which it is mixed in its firſt ſtate, it is very ſoon altered by ſpontaneous decompoſition. Various methods have been contrived to prevent this effect from taking place, in order that this wholeſome and agreeable acid might be preſerved for uſe in long voyages, or other domeſtic occaſions.

— by oil:

The juice may be kept in bottles under a thin ſtratum of oil, which indeed prevents, or greatly retards, its total decompoſition; though the original freſh taſte ſoon gives place to one which is much leſs grateful.

— by evaporation:

In the Eaſt Indies it is evaporated to the conſiſtence of a thick extract. If this operation be carefully performed by a very gentle heat, it is found to be very effectual. When the juice is thus heated, the mucilage thickens, and ſeparates in the form of flocks; part of which ſubſides, and part riſes to the ſurface: theſe muſt be taken out. The vapours which ariſe are not acid. If the evaporation be not carried ſo far as to deprive the liquid of its fluidity, it may be long preſerved in well-cloſed bottles; in which, after ſome weeks ſtanding, a farther portion of mucilage is ſeparated, without any perceptible change in the acid.

— by freezing.

Of all the methods of preſerving lemon juice, that of concentrating it by froſt appears to be the beſt; though, in the warmer climates, it cannot conveniently be practiſed. Lemon juice, expoſed to the air in a temperature of between 50° and 60°, depoſits in a few hours a white ſemi-tranſparent mucilaginous matter, which leaves the fluid, after decantation and filtration, much leſs alterable than before. This mucilage is not of a gummy nature, but reſembles the gluten of wheat in its properties: It is not ſoluble in water, when dried. More mucilage is ſeparated from lemon juice by ſtanding in cloſed veſſels. If this depurated lemon juice be expoſed to a degree of cold of about ſeven or eight degrees below the freezing point, the aqueous part will freeze, and the ice may be taken away as it forms; and if the proceſs be continued until the ice begins to exhibit ſigns of acidity, the remaining acid will be found to be reduced to about one-eighth of its original quantity, at the ſame time that its acidity will be eight times as intenſe; as is proved by its requiring eight times the quantity of alkali to ſaturate an equal portion of it. This concentrated acid may be kept for uſe; or, if preferred, it may be made into a dry lemonade, by adding ſix times its weight of fine loaf ſugar in powder *.

Depuration of the acid of lemons:

— by congelation:

The above proceſſes may be uſed when the acid of lemons is wanted for domeſtic purpoſes; becauſe they leave it in poſſeſſion of the oils, or other principles, on which its flavour peculiarly depends. But in chemical reſearches, where the acid itſelf is required to be had in the utmoſt purity, a more elaborate proceſs muſt be uſed. Boiling lemon juice is to be ſaturated with powdered chalk, whoſe weight is to be noted. The neutral ſaline compound is ſcarcely more ſoluble in water than ſelenite: it therefore falls to the bottom; while the mucilage remains ſuſpended, in the

—by the chemical affinities.

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* Georgius, quoted by Fourcroy, iv. 33.

Depuration of acid of lemons.

the watery fluid which muſt be decanted off. The remaining precipitate muſt then be waſhed with warm water until it comes off clear. To the powder, thus edulcorated, a quantity of vitriolic acid, ſufficient to ſaturate the chalk, and diluted with ten parts of water, muſt be added, and the mixture boiled a few minutes. The vitriolic acid combines with the lime, and forms ſelenite, which remains behind when the cold liquor is filtered; while the diſengaged acid of lemons remains diſſolved in the fluid. This laſt muſt be evaporated to the conſiſtence of a thin ſyrup; and vitriolic acid muſt be then added in ſmall portions, to precipitate the lime, if any ſhould ſtill remain in combination with acid of lemons. When no more precipitate is afforded by the addition of vitriolic acid, a farther evaporation ſeparates the pure acid of lemons in cryſtals. It is neceſſary that the vitriolic acid laſt added ſhould be rather in exceſs; becauſe the preſence of a ſmall quantity of lime will prevent the cryſtallization. This exceſs will be found in the mother water *.

Characters.

The concrete acid of lemons remains conſiſtent in the air, is very ſoluble in water, and exhibits ſtrong acid properties. Its watery ſolution is decompoſed by a ſlow putrefaction. It unites with the alkalis and earths, ſilex excepted; and forms peculiar neutral ſalts, which have not yet been much examined. Several of the metallic ſubſtances are likewiſe acted upon by it; and it would probably diſſolve all their calces.

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* Scheele's Eſſays, Eng. Tranſlation, p. 361; or Crell's Journal for 1784.

VEGETABLE ACIDS.

Method of purifying the acid of apples.

The acid which abounds in ſour or unripe fruits exhibits diſtinct properties. As it is plentifully obtained from apples, the firſt examiner, Scheele, has denominated it the acid of apples. In order to obtain it, the juice of ſour apples is expreſſed from the fruit, and ſaturated with vegetable alkali. To this liquor a ſolution of the vitriolic ſalt of lead muſt be very gradually added. A double decompoſition takes place. The vitriolic acid combines with the alkali, and forms vitriolated tartar; at the ſame time that the acid of apples, uniting with the lead, forms an inſoluble precipitate. When the precipitate nearly ceaſes to fall down, the ſolution of ſugar of lead muſt be added cautiouſly, by a drop at a time, until no more precipitate is afforded. The vitriolated tartar may be waſhed off from the precipitate; and diluted vitriolic acid being then poured on the precipitate, ſugar of lead is again formed, and the acid of apples is ſet at liberty.

Separation of the acids of lemons and of apples.

In ſuch fruits as contain the acid of lemons as well as that of apples, the ſeparation of one from the other is accompliſhed by the following proceſs. The juice of gooſeberries, for example, is evaporated to the conſiſtence of ſyrup: pure ardent ſpirit being poured upon this, diſſolves the acids, and leaves the mucilage, which may be ſeparated by filtration. The ardent ſpirit being then evaporated, and water added, the acids muſt be ſaturated with chalk. The ſolution being boiled for a few minutes, the calcareous ſalt of lemons falls to the bottom, on account of its difficult ſolubility; while the other ſalt, conſiſting of the acid of apples, united to lime, remains ſuſpended, and may conſe-

Acid of apples.

conſequently be decanted off. This neutral ſalt not being ſoluble in ſpirit of wine, may be precipitated by the addition of a proper quantity of that fluid; which, at the ſame time, deprives it of a portion of ſaponaceous and ſaccharine matter. The coagulum, or precipitate, which conſiſts for the moſt part of the acid of apples, perfectly neutralized by lime, may be diſſolved in boiling water. An addition of ſugar of lead forms a precipitate by double affinity, as in the firſt caſe, conſiſting of the acid of apples united to lead; and this waſhed precipitate may be decompoſed by the addition of diluted vitriolic acid, which combines with the lead, and ſets the acid of apples at liberty.

Characters.

This acid exhibits peculiar properties. It cannot be obtained in cryſtals; and forms deliqueſcent ſalts with the three alkalis, and alſo with magneſia. Its ſaline combination with lime is cryſtallizable; and with clay it forms a ſalt of very ſparing ſolubility. It diſſolves iron, with which it forms a ſalt that does not cryſtallize. With zinc, it forms a ſalt which affords beautiful cryſtals. It precipitates the nitrous ſolutions of mercury, lead, ſilver, and gold, in the metallic ſtate: when nitrous acid is diſtilled from it, it is converted into acid of ſugar.

The aſtringent principle.

Many vegetable ſubſtances, ſuch as the huſks of nuts, the bark of the oak, the nut-gall, and other vegetable matters, abound with a ſubſtance which has been diſtinguiſhed by the name of the aſtringent principle. Its diſtinguiſhing character is that of precipitating iron from its ſolutions in acids, of a black colour. The nut-gall is chiefly uſed for this, and other purpoſes wherein the application of this property is required; and, as it reſembles acids in its properties, the principle has been called the acid of galls.

Acid of galls obtained in ſolution:

The acid of galls is obtained by macerating the nut-gall in water. This infuſion reddens turnſole and blue paper. The acid is ſoluble in oils, ardent ſpirit, and ether. Acids diſſolve it, without impairing its property of forming a black precipitate with the ſolutions of iron: the diſtilled products of nut-galls likewiſe poſſeſs the ſame property. It decompoſes metallic ſolutions, and combines with their calces: gold and ſilver are precipitated by it in the metallic ſtate. It acts upon and diſſolves iron directly.

—in the cryſtallized form.

To obtain the acid of nut-galls in a cryſtallized form, one pound of the powder of galls muſt be added to ſix pounds of diſtilled water, and left to digeſt for a fortnight, at the temperature of between 70 and 80 degrees; after which, the fluid muſt be filtered, and left to evaporate ſpontaneouſly in the open air, in a ſtone-ware or glaſs veſſel. The fluid becomes mouldy, and covered with a thick glutinous pellicle; abundance of glutinous flocks fall down; and in the courſe of two or three months the ſides of the veſſel appear covered with ſmall yellowiſh cryſtals, which are likewiſe very abundant at the under ſurface of the pellicle which covers the liquor. The fluid muſt then be decanted; and ardent ſpirit, being poured upon the mucilaginous depoſition, the cryſtals and the pellicle, diſſolves the ſalt by the aſſiſtance of heat, without touching the mucilage; and, by evaporation of this ſpirituous ſolution, the pure gallic acid is obtained in ſmall brilliant cryſtals, of a grey colour inclining to yellow.

This

Page 300. General characters and habitudes of the acid of galls.

This acid, on account of its long expoſure to the air, may conſiſt either of a principle exiſting in the galls, or of that principle converted into an acid. It has the following properties: It precipitates martial vitriol, and other ſalts of iron, of a beautiful black colour, and ſtrongly reddens the tincture of turnſole: when heated, with contact of air, it ſwells up, and burns, leaving a coal behind of difficult incineration: by diſtillation, with a gentle heat, part of the acid comes over diſſolved in the water of cryſtallization: another portion ſublimes undecompoſed in the form of ſilky cryſtals; and a ſtrong heat ſeparates a few drops of oil, with fixed and inflammable air.

The acid of galls is ſoluble in twenty-four parts of cold water, or three of boiling water. It is much more ſoluble in ſpirit of wine; four parts of this being ſufficient at the common temperature, or one when boiling hot. With lime, magneſia, or ponderous earth, it forms ſalts which are ſoluble in water: it unites readily with the alkalis, and forms compounds, which have not been much attended to. The action of the nitrous acid converts it into the acid of ſugar. This acid precipitates gold, ſilver, mercury, copper, iron, and biſmuth, from their ſolutions; but it does not affect thoſe of platina, zinc, tin, cobalt, and mangeneſe.

Benzoin.

The fragrant reſin, called benzoin, affords a peculiar concrete acid by ſublimation, which is about one tenth of the weight of the reſin itſelf, but varies in different ſpecimens. This acid exiſts ready formed in the benzoin; but cannot eaſily be waſhed out by water, Method of obtaining the acid of benzoin in the humid way.

water, on account of the reſin which defends it. The beſt method of obtaining it, in the humid way, is the following: Lime-water is made by ſlacking four ounces of quick-lime with twelve ounces of water; and, as ſoon as the ebullition is over, eight pounds more of water are to be added. Six ounces of this lime-water are to be mixed by agitation with one pound of benzoin in powder, and the whole of the lime-water is then to be added; the mixture being expoſed to heat over a gentle fire for half an hour (during which time it muſt be continually agitated, to prevent the powder from coagulating), is afterwards ſuffered to cool, and ſettle for ſeveral hours. The clear liquor muſt then be decanted, and the reſidue boiled for half an hour with eight pounds of water; which, after ſubſidence and decantation, muſt be added to the clear fluid of the firſt boiling. The ebullition of the reſidue of the matter muſt be again twice repeated, and the decanted lixiviums added to the foregoing. All theſe waters are then to be evaporated to two pounds; during which operation a ſmall quantity of reſin falls down. When the evaporated liquor is cool, a quantity of marine acid muſt be added drop by drop, with conſtant ſtirring, till there be no more precipitation, or till the maſs has a ſouriſh taſte. The precipitate is the acid of benzoin.

Rationale.

The rationale of the above proceſs is this: The lime unites with the acid of benzoin during the ebullition: the evaporation ſeparates a ſmall quantity of reſin; and diminiſhes the aqueous fluid ſo much, that in the ſubſequent part of the operation the acid of benzoin may fall down, and be ſeparated for want of

Method of obtaining the acid of benzoin.

a ſufficient quantity of water to diſſolve it. The marine acid, which is added laſt of all, ſeizes the lime by its ſtronger affinity, and forms a ſoluble ſalt; while the acid of benzoin, which is diſengaged, falls down, on account of its ſparing ſolubility. The acid thus obtained has the form of a very fine powder. If it be required in the form of ſilky threads, it may be diſſolved in boiling water, and ſtrained through a cloth. As cold water diſſolves little more than one five hundredth part of its weight, though boiling water diſſolves about one twentieth of this acid, the greateſt part of the acid ſeparates by cooling.

Its characters.

The acid of benzoin combines with the ſoluble earths and alkalis, and forms compounds, which have been little attended to. It is ſoluble in the vitriolic and nitrous acids; and may be again ſeparated, without alteration, by the addition of water. Its habitudes with theſe acids, particularly the latter, when heated, have not been ſatisfactorily aſcertained. If its nature be changed by diſtillation with nitrous acid, it ſeems probable that it is effected with much more difficulty than is experienced with other vegetable acids.

CHAP.

CHAP. IV.

CONCERNING THE ACIDS OF TARTAR AND OF SORREL.

VEGETABLE ACIDS.

Tartar.

THE two acids which are uſually found in combination with a portion of the vegetable alkali, are the acid of tartar and of wood ſorrel. Tartar has for a long time been conſidered as one of the products of the vinous fermentation; but it exiſts ready formed in muſt, in verjuice, and is likewiſe obtained in other chemical proceſſes with vegetables. However, it is obtained, for all the purpoſes of commerce, from wine; during the inſenſible fermentation of which liquid, it is gradually depoſited on the ſides of the caſks.

Cream and cryſtals of tartar.

Crude tartar is ſeldom uſed in medicine, or philoſophical chemiſtry; the refined tartar is known by the name of cream, or cryſtals, of tartar. The purification of this ſalt is effected by diſſolving it in boiling water, filtering and ſuffering it to cryſtallize by cooling; the cryſtals are again boiled, together with an argillaceous earth, to deprive them of their impurities, which are carefully ſcummed off; or elſe with whites of eggs, which anſwer the ſame purpoſe. When no more ſcum ariſes, a ſaline pellicle is formed at the top of the liquor, at the ſame time that the cryſtallization goes forward at the bottom. This ſalt, after the earth is waſhed off with cold water, is ſold under the name of cream, and cryſtals of tartar. The cream of tartar conſiſts of the minute cryſtals which are formed at the top of the liquor, and the cryſtals of tartar are formed at the bottom.

Characters of purified tartar.

The taſte of this purified ſalt is leſs vinous than that of the crude tartar. When expoſed to heat, it boils up, emits an epyreumatic ſmell, and becomes black and coaly; a ſtronger heat in an open fire entirely diſſipates its acid part, and leaves the vegetable alkali in a mild ſtate, or combined with fixed air. Its volatile products, by a gradual fire, are water, an acid, and an epyreumatic oil, which is followed by ſome volatile alkali, and a large quantity of fixed air. Cryſtals of tartar are ſoluble in twenty-eight parts of boiling water; three-fourths of the ſalt are depoſited in cooling. If the ſolution of this ſalt be left expoſed to the air, it is very ſlowly decompoſed; mucilage is depoſited, the acid diſappears, and after eighteen months the liquid is found to contain the vegetable alkali, amounting to nearly one-fourth of the weight of the tartar. This quantity of alkali being nearly the ſame as is afforded by the incineration of tartar, is a proof that the vegetable alkali is not a product of fire, as was formerly ſuppoſed.

Habitudes.

The habitudes of tartar with clay and ponderous earth have not been aſcertained. Magneſia forms with it a ſoluble ſalt. Chalk unites with the exceſs of acid in the tartar, and ſeparates the neutral ſalt; conſiſting of the vegetable alkali, ſaturated with the tartareous acid, which is known by the name of ſoluble tartar. If the vegetable alkali be added to a ſolution of cream of tartar, in ſuch a quantity as to ſaturate it, the ſame neutral

Soluble tartar.

neutral ſalt, or ſoluble tartar, will be formed. This has a bitter taſte, and is decompoſed by heat, affording the ſame volatile products as cream of tartar. It is ſoluble in four parts of water heated to 110°, and affords cryſtals which are ſlightly deliqueſcent.

Soluble tartar.

It is a curious fact, though by no means ſingular in the hiſtory of neutral ſalts, that two very ſoluble ſubſtances, ſuch as the vegetable alkali, and the acid of tartar, ſhould compoſe a ſalt of ſo little ſolubility as the cryſtals of tartar; more eſpecially, as the point of the greateſt difficulty of ſolution is not that at which they are ſaturated, but that in which the acid ſo conſiderably abounds.

Curious fact.

If to twenty ounces of purified tartar, diſſolved in four pounds of boiling water, the pure cryſtallized mineral alkali be added, until the ſaturation be complete, as may be judged by any additional quantity producing no effervеſcence; the alkali laſt added will combine with the ſuperfluous acid of the tartar, and form the neutral combination called the ſalt of Seignette, or Rochelle ſalt; at the ſame time that the reſidue of the tartar will become converted into ſoluble tartar. By evaporating the liquor nearly to the conſiſtence of ſyrup, the Rochelle ſalt is obtained in beautiful regular priſms, of ſix or eight ſides, which effloreſce in the air, and are decompoſed by heat in the ſame manner as ſoluble tartar.

Manufacture of Rochelle ſalt.

By the ſame treatment with volatile alkali, an ammoniacal tartareous ſalt is formed, which affords cryſtals that effloreſce in the air.

Ammoniacal ſalt of tartar.

If the mineral acids be added to tartar, they combine with its alkali, and form the ſame ſalts as they would have produced by direct union with the vegetable alkali.

Tartar.

Tartar has long been an object of attention with chemiſts, and it is uſed as an acid in many of the arts. This ſalt appears to be capable of uniting without decompoſition, and forming triple ſalts with moſt of the metals.

Method of obtaining the acid of tartar:

The pure acid of tartar may be obtained by ſaturating three parts of cream of tartar with chalk or lime; the former of which combines with the ſuperfluous acid, and the latter ſeizes the whole. The calcareous tartar, which, on account of its inſolubility, remains at the bottom, is then to be well waſhed, and digeſted with about one part of vitriolic acid, together with a ſufficient quantity of water. In this manner the acid of tartar is diſengaged. The ſelenite formed by the combination of the vitriolic acid and the lime, will be ſeparated, and fall down, by evaporating the water; and the acid which remains may be cryſtallized by further evaporation and cooling.

— or otherwiſe.

Or, more ſimply, one pound of cream of tartar may be boiled in five or ſix pounds of water, and a quarter of a pound of clear and colourleſs denſe vitriolic acid may be added by little and little. When a complete ſolution is obtained, the fluid will then contain diſengaged acid of tartar, together with vitriolated tartar, or the neutral ſalt, formed by the union of the vitriolic acid with the vegetable alkali. The vitriolated tartar, being a ſalt of ſparing ſolubility, will be precipitated by continuing the boiling. When the liquor is evaporated to one half, it is to be filtered; and if, upon further evaporation, any thing more is precipitated,

pitated, it muſt be filtered again. The clear liquor being then reduced to the conſiſtence of a ſyrup, and ſet by in a temperate or rather warm place, will afford fine cryſtals of tartareous acid, equal in weight to half the cream of tartar employed. If too ſmall a quantity of vitriolic acid has been uſed, part of the cream of tartar will not be decompoſed, but will ſeparate from the liquor along with the vitriolated tartar. It is better therefore to uſe too little rather than too much.

Acid of tartar:

—its characters,

The cryſtallized tartareous acid melts, fumes, becomes black, and burns, by the contact of ignited bodies. By diſtillation it affords an acid phlegm, a ſmall quantity of oil, and much fixed air, together with inflammable air; leaving behind a coaly reſidue, which contains neither acid nor alkali.

and habitudes.

The cryſtals of tartareous acid do not change by expoſure to air; they are much more ſoluble in water than cream of tartar itſelf. This acid diſſolves clay, and forms a ſalt which, by evaporation, aſſumes a clear gummy conſiſtence, and does not deliqueſce in the air. The ſame appearance is exhibited with magneſia: with lime, it forms a ſalt which is ſcarcely at all ſoluble; a due proportion of vegetable alkali converts it into cream of tartar, which falls down if the water of ſolution be not ſufficiently abundant, but is diſſolved again if more alkali be added, ſo as to convert it into ſoluble tartar. Theſe ſynthetical operations ſhew that the tartareous acid is not altered by the proceſs of extracting it from cream of tartar.

With the mineral alkali it forms the Rochelle ſalt, and with volatile alkali it forms a cryſtallizable ſalt.

In this laſt combination there is a term at which cryſtals of ſparing ſolubility, like thoſe of cream of tartar, are formed; and in this caſe likewiſe the acid of tartar is far from being ſaturated with the alkali.

This acid is convertible into the ſaccharine acid by diſtillation with ſtrong acid of nitre: and it is converted into acetous acid by digeſtion with water and ardent ſpirits.

Salt of ſorrel:

Salt of ſorrel is a cryſtallized ſalt; ſo denominated becauſe it is obtained from the wood ſorrel, or oxalis aceto-ſella of Linnæus, for the purpoſes of commerce; though it may be obtained from ſome other plants. It is in white cryſtals, whoſe figure has not been well determined, on account of their minuteneſs. When it is expoſed to diſtillation in a retort, the acid is partly decompoſed; a conſiderable quantity of acid phlegm comes over, which is without ſmell or colour, and conſiſts of the acid itſelf, ſcarcely altered; and the reſidue affords vegetable alkali, amounting to ſomewhat more than one third of the weight of the ſalt. Expoſure to air does not alter the ſalt of ſorrel. It is very ſparingly ſoluble in cold water: but boiling water may take up one ſixth part, or more, of its weight; the quantity varying according to the ſtate and purity of the ſalt, which ſeems to vary in different ſpecimens.

— characters:

— action upon various ſubſtances.

Salt of ſorrel acts upon various ſubſtances without decompoſition. With ponderous earth, magneſia, vegetable alkali, and volatile alkali, it forms triple ſalts. Lime decompoſes it by ſeizing the whole of the acid, and diſengaging the alkali. The attraction of this acid for lime is ſo ſtrong, that it cannot be diſengaged from

Method of purifying the acid of ſorrel.

from it by any other acid: another proceſs is therefore neceſſary to be uſed for obtaining it. With this intention, the ſuperabundant acid is to be ſaturated with volatile alkali; and into this ſolution muſt be poured a ſolution of ponderous earth in the nitrous acid. The laſt-mentioned acid combines with the alkalis, forming nitrous ammoniac, and common nitre, both which remain in ſolution; while the ponderous earth, combining with the acid of ſorrel, forms an inſoluble compound, which falls to the bottom. This precipitate, after being well waſhed, may be decompoſed by the addition of vitriolic acid, which ſeizes the earth, and likewiſe forms an inſoluble combination, while the acid is ſet at liberty. After decantation of the clear liquid, it muſt be aſſayed by pouring into it a little at a time of the boiling hot ſolution of ponderous earth in the acid of ſorrel. If there be any exceſs of vitriolic acid, a precipitate will be formed by its union with the ponderous earth. A due evaporation and cooling of this liquor afford the acid of ſorrel, in priſmatic four-ſided cryſtals or ſquare plates.

Characters.

This acid has a conſiderable degree of ſtrength. Expoſed to heat in a retort, it falls into powder, with the loſs of three tenths of its weight, after which it melts, boils up, at the ſame time that its colour changes to a brown. An acid phlegm comes over, and part of the acid ſublimes without alteration. Fixed air and inflammable air are diſengaged during this decompoſition of the acid; and their quantity is greater, the more violent the heat.

Combinations.

Boiling water diſſolves its own weight of this concrete acid ſalt, half of which is ſeparated in cryſtals by

Combinations of the acid of ſorrel.

by cooling. It diſſolves clay, and affords a deliqueſcent maſs by evaporation. With ponderous earth it forms a ſalt ſcarcely ſoluble, except there be an exceſs of acid; in which caſe it affords tranſparent cryſtals, which become opake, powdery, and inſoluble, when the exceſs of acid is taken up by boiling water. With magneſia, it forms a white powdery ſalt; and with lime it forms an inſoluble compound, which cannot be decompoſed in the moiſt way, becauſe the affinities of theſe two ſubſtances are ſtronger than any which exiſt between either of them and other known bodies. From this property, the acid of ſorrel is uſed as the teſt of the preſence of lime, which it precipitates from all its combinations.

Syntheſis.

If vegetable alkali be gradually added to a ſolution of this acid in water, a precipitate falls down, which is the ſalt of ſorrel, and contains the acid in exceſs. A farther addition of alkali ſaturates the acid, and forms a very ſoluble ſalt, which is capable of cryſtallizing, if the alkali be in exceſs. With an exceſs of the mineral alkali it forms a ſalt of ſparing ſolubility. With volatile alkali it affords a cryſtallizable ſalt; and with both theſe alkalis, if the acid be in exceſs, it forms a leſs ſoluble ſalt, ſimilar to what happens with the vegetable alkali.

It acts on ſeveral of the metals directly, but in general combines more readily with their calces.

This acid does not differ from the acid of ſugar. Treatment with nitrous acid converts it into acetous acid and fixed air; or totally into the latter, if the action be rapid.

CHAP.

CHAP. V.

CONCERNING THE VEGETABLE ACIDS PRODUCED OR DEVELOPED BY DESTRUCTIVE DISTILLATION, OR BY THE ACTION OF NITROUS ACID.

VEGETABLE ACIDS: ARTIFICIAL.

Conſiderations on the compoſition and decompoſition of vegetable bodies.

IN the courſe of the preceding accounts of the vegetable acids, it may be obſerved, that they are all ſubject to great alterations by the action of chemical agents; and they are all ſubject to ſpontaneous decompoſition. They ſeem to obtain their acid properties by the combination of a baſe with the vital part of the air, in the ſame manner as has been more fully ſhewn with regard to the mineral acids; but they appear to be of too compounded a nature to retain the order or arrangement of their component parts through thoſe great varieties of temperature, to which in general the mineral acids may be ſubjected. Heat alters the arrangement of their component parts, and ſeparates them from each other in a new form. The products of all vegetable ſubſtances including theſe acids are found, when urged by fire, to be water, fixed air, inflammable air, oil, coal, and alkali. If we conſider water as decompoſable, and conſiſting of vital and inflammable air; if we conſider oil as compoſed of fixed air and inflammable air; and again, whether we admit charcoal to conſiſt chiefly of inflammable air, according to the opinion of ſome chemiſts, or of the

Simplicity and ſmall number of vegetable principles.

the peculiar baſis of fixed air, according to others; and, laſtly, if fixed air be allowed to conſiſt of charcoal united to vital air, whether the charcoal be conceived as a peculiar ſubſtance, or as inflammable air in a ſtate of condenſation; we ſhall at length find that the component parts of vegetables are very few; inſomuch that, if the foregoing poſitions were clearly eſtabliſhed, they would conſiſt either of charcoal, vital air, and inflammable air, or elſe of vital air and inflammable air only. From the various proportions of theſe, in different ſtates of condenſation, it would follow, that water, fixed air, oils, mucilages, and acids, are produced; and that the beautiful variety of nature ariſes from this arrangement and combination.

Empyreumatic acids.

The firſt action of fire upon the vegetable acids does not in general alter their combinations ſo much, but that ſome other acid comes over together with the elaſtic products. Theſe acids, which on account of the peculiar ſmell which they obtain from the fire are called empyreumatic, would probably, on examination, be found to be of various kinds. Thoſe which have hitherto engaged the attention of chemiſts, are the empyreumatic acid of tartar; the empyreumatic acid of ſugar or mucilage, formerly called ſpirit of honey; and the empyreumatic acid of wood, which is ſuppoſed to be the ſame in all woods, and has been diſtinguiſhed by the name of ſpirit of box.

Empyreumatic acid of tartar.

The empyreumatic acid of tartar, is the acid phlegm which comes over when cream of tartar is expoſed to diſtillation. This acid is impure, on account of ſome oil which comes over with it, and from which

VEGETABLE ACIDS: ARTIFICIAL.

Empyreumatic acid of tartar:

it can only be ſeparated by the funnel; becauſe it dilates ſo ſuddenly, when an attempt is made to rectify it by a ſecond diſtillation, that it burſts the veſſels. The acid properties of this fluid are ſufficiently apparent, though it does not redden the tincture of violets, as it does turnſole and blue paper. It forms peculiar compounds with the earths and alkalis, which have not been much examined, but are very different from thoſe afforded by the acid of tartar.

— of ſugar or mucilage:

When inſipid gummy ſaccharine or farinaceous mucilages are expoſed to diſtillation, an empyreumatic acid comes over, of a reddiſh yellow colour, and a bitter, acrid, and ſour taſte. By rectification with the addition of clay, the acid comes over clear, and leſs empyreumatic. It does not afford cryſtals, but may be concentrated by freezing, which converts its aqueous part into ice. In this ſtate it ſtrongly reddens blue vegetable colours, and forms a red ſpot where it falls on the ſkin. By diſtillation, cautiouſly managed in cloſe veſſels, it may be converted for the moſt part into fixed and inflammable air.

The empyreumatic acid of ſugar attacks and diſſolves the ſoluble earths and alkalis. It corrodes lead, copper, tin, and iron: but the compounds it forms with theſe bodies have been little attended to.

— of wood.

Box, birch, and other woods, when expoſed to diſtillation, afford that peculiar acid, which is ſo offenſive to the eyes when the ſmoke of a ſmothering wood fire forces itſelf into an apartment. This acid has conſiderable ſtrength. The oil which comes over with

VEGETABLE ACIDS: ARTIFICIAL.

Acid of wood.

with it, may be ſeparated, either by ſtanding for ſome months, or by rectification. It cannot be obtained in a concrete form. A ſtrong heat decompoſes it. With earthy and alkaline baſes it forms peculiar ſalts, whoſe general properties have not been minutely enquired into. As the properties of the acid obtained from a conſiderable variety of woods have proved to be the ſame, it is preſumed that all woods contain this common acid, or at leaſt that combination of principles which conſtitutes its baſe.

Obſervations on the effect of nitrous acid upon vegetable bodies.

Since the acidification of combuſtible ſubſtances is evidently produced by the application or combination of vital air; and as, in all the operations of chemiſtry, effects may be produced by one mode of combination, which are impracticable in others; it becomes neceſſary, in chemical reſearches, to try every means which can be deviſed. Few vegetable acids are artificially produced by the direct application of vital air to the principles of that claſs of bodies; but many experiments have been made by abſtracting the nitrous acid from vegetables by diſtillation. This acid, as we have frequently had occaſion to obſerve, is very eaſily decompoſed, when applied to combuſtible bodies, which attract its vital air, and diſengage either nitrous or phlogiſticated air, as we have explained in our chapter upon that acid. It has likewiſe been obſerved, in various parts of the preſent ſection, that this acid, when repeatedly diſtilled from gums, mucilages, ſugar, the acids of tartar, of apples, and of gall, produces the peculiar acid which has been called the acid of ſugar; and, if the abſtraction be repeated too often, the acid of

Chap. III. IV.

of ſugar itſelf is converted into fixed air. From this view of the ſubject, together with other facts, it has been inferred, that a greater or leſs proportion of vital air, united with one general principle abundantly exiſting in charcoal, whether this principle be inflammable air or not, produces all the various acids of vegetables. Thus tartar, which is the leaſt acidified, is ſaid to become converted into the acid of apples by treatment with nitrous acid. The acid of apples, by a continuance of the operation, becomes converted into acid of ſugar, or acid of ſorrel, which are the ſame thing. The ſame proceſs, further continued, affords vinegar *, which comes over. Hence it ſhould ſeem that, according to the greater progreſs which the operation of combuſtion, or the combination of vital air with the baſe (which at the ſame time, according to the ancient theory, is ſuppoſed to be more dephlogiſticated), the acids of tartar, of apples or unripe fruit, of ſorrel or ſugar, of vinegar, and laſtly, of fixed air, are produced. In this order of proceeding, the acids become more and more perfect, and leſs eaſily decompoſable: and on this account probably it is, that attempts to reverſe the proceſſes have not hitherto been attended with much ſucceſs.

The progreſs of acidification in vegetable bodies.

Since the diſcovery that the acid of ſugar does not differ from that of ſorrel but in containing a ſmall proportion of alkali, the procuring of the former in the expenſive way of diſtillation with nitrous acid, is

Difference between the acids of ſugar and ſorrel.

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* See Scheele's Eſſays, Engliſh tranſlation, page 385; and the Journal de Phyſique for January 1788, page 59.

become unneceſſary. We ſhall, nevertheleſs, deſcribe the proceſs here, as an example of that method of operating.

The proceſs for converting ſugar into an acid.

Three ounces of ſtrong nitrous acid, whoſe ſpecific gravity was nearly 1.567, were mixed in a tubulated retort with one ounce of the fineſt ſugar in powder. Much nitrous air eſcaped in red fumes, formed by combination with the vital air of the atmoſphere. A receiver was then adapted, and the liquor gently boiled. As ſoon as the mixture had acquired a dark brown colour, three additional ounces of nitrous acid were added, and the boiling was continued until the coloured and fuming acid had entirely diſappeared. The liquor being then poured out, afforded ſmall priſmatic cryſtals by cooling, which are the acid of ſugar. The lixivium being again treated in the ſame manner, with two ounces of nitrous acid, afforded an additional portion of acid of ſugar by cooling; and the remaining glutinous liquor, treated at different times with ſmall quantities of nitrous acid, amounting in the whole to two ounces, and evaporated to dryneſs, afforded a ſaline maſs: and, laſtly, the whole was depurated by repeated ſolutions and cryſtallizations in water. In this way, with three parts of ſugar, and thirty of nitrous acid, the quantity of one part of acid of ſugar is obtained.

Obſervation.

The above proceſs is taken from Bergmann: but it may be obſerved that weak nitrous acid, or common aqua fortis, will anſwer the purpoſe as well as the concentrated acid; and that, where it is not an object to collect the acid which comes over, there will be no need of any receiver, or other apparatus, except a matraſs, or Florence flaſk, to perform the operation in a chimney where there is a proper draught of air to carry off the acid fumes.

Acid of camphor.

The acid of camphor * is produced by diſtilling the nitrous acid eight ſucceſſive times from camphor. It is of a concrete cryſtalline form, of a bitter taſte, and reddens the tinctures of violets and turnſole. It differs from the acid of ſugar in not ſeparating lime from the marine acid. With vegetable alkali it forms a ſalt in regular hexagons; with mineral alkali, a ſalt in irregular cryſtals; with volatile alkali, priſmatic or needle-formed cryſtals; and with magneſia, a pulverulent ſoluble ſalt. It diſſolves ſeveral metallic ſubſtances. But ſubſequent enquiries are wanting to eſtabliſh the peculiar nature and properties of this acid.

Acid of cork.

By diſtilling four times its weight of nitrous acid from cork, a yellowiſh thick acid matter is obtained, which is ſoluble in water, and has an auſtere bitteriſh taſte. It does not cryſtallize, but becomes conſiſtent like wax by evaporation; is ſoluble in ardent ſpirit; forms deliqueſcent ſalts with the earths and alkalis; and has as ſtrong an attraction for lime as the acid of ſugar †.

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* Koſegarten, Nouv. de la Republ. des. Lettres, Année 1785. Nos. 42 and 44; quoted by Fourcroy, Elem. Chem. iv. 104, edition of 1789.

† Brugnatelli, in the Journal de Phyſique, Auguſt 1787; or Crell's Annals for the ſame year.

CHAP.

CHAP. VI.

ON THE DESTRUCTIVE DISTILLATION OF VEGETABLE SUBSTANCES.

VEGETABLE PRODUCTS BY FIRE.

Deſtructive diſtillation.

IN the foregoing chapters we have occaſionally treated of the decompoſition of vegetables by deſtructive diſtillation, and have deſcribed the volatile products it affords. As the immediate principles of organized ſubſtances are for the moſt part very compounded, and the extreme temperature produced in this method tends to reduce them to their primary component parts, it is evident that very little can be learned in this way concerning that on which the various properties of thoſe ſubſtances depend. But as the chemiſt ought to neglect none of the methods he poſſeſſes of producing changes in bodies, this proceſs may have its uſe when compared with others, and more eſpecially when we ſhall have arrived at that knowledge of the firſt principles of organized ſubſtances, which from a variety of facts, and the late rapid progreſs of chemiſtry, we have reaſon to hope for. We ſhall therefore proceed to deſcribe the general phenomena of deſtructive diſtillation.

This proceſs conſiſts merely in expoſing any organized ſubſtance to heat in a retort, placed in a reverberatory furnace. The ancient chemiſts, who paid no attention to the elaſtic products, except ſo far as their

Decompoſition of vegetables by fire.

their expanſive force impeded their operations, uſually drilled a ſmall hole in the upper part of the receiver for their eſcape. Modern chemiſtry proceeds in a more ſcientific manner, by uſing the pneumatic apparatus, fig. 21. The firſt product which comes over in the diſtillation of vegetables, is a watery fluid, containing acid and odorant principles. In proportion as the deſtruction of the vegetable proceeds, the phlegm becomes deeper coloured, and more ſaline. Next follows a coloured oil, which becomes of a darker hue as the diſtillation proceeds, and varies greatly according to the nature of the plant; for it conſiſts chiefly of the eſſential oil, which comes over in a foul ſtate, and differs in its fixity, denſity, fuſibility, and all its other properties according to the nature and quantity of the eſſential oil which predominates in it. All the products obtained in this way have a peculiar burned ſmell, which chemiſts diſtinguiſh by the name of empyreumatic. If the vegetable contain volatile alkali, or its component parts, this ſubſtance uſually ſublimes when the oil comes over. The elaſtic fluids which paſs into the apparatus of inverted veſſels are chiefly inflammable air, or fixed air, or a mixture of both (probably in combination), which is heavier than pure inflammable air, and burns with a lambent blue flame, inſtead of detonating like that elaſtic fluid. The heat muſt be very gradually raiſed, and the receivers changed from time to time, in this method of decompoſition; otherwiſe the products which come over will be confounded together, and the reſults will of courſe be more fallacious than they would otherwiſe have been. The fixed reſidue conſiſts of charcoal, a ſmall portion of alkali, and a very minute quantity of earth.

Empyreumatic oils.

The empyreumatic oils which come over in theſe diſtillations may all be rendered colourleſs, and ſoluble in ardent ſpirit by rectification. In this manner it appears therefore that the fixed oils of vegetables are converted into volatile or eſſential oils; from which, as well as from other circumſtances, it is rendered probable that theſe oils differ from each other only in the proportion of their component parts.

Charcoal:

The black, ſonorous, brittle, light ſubſtance, called charcoal, uſually retains the figure of the vegetable from which it was produced, unleſs the greater part of the vegetable conſiſted of fluids, which, in their diſſipation, deſtroy the connection of the more fixed parts. In the latter caſe the quantity of charcoal is much leſs than in the former. It is a ſingular fact, that this ſubſtance, when well burned, is a perfect conductor of electricity; though the electric matter is not conveyed at all through wood which is ſimply baked or dried. The charcoal of oily or bituminous ſubſtances is of a light pulverulent form, and riſes in ſoot. This charcoal of oils is called lamp-black.

—conducts electricity:

Charcoal reſiſts the moſt violent heat in cloſed veſſels. If it be ignited, it abſorbs elaſtic fluids with great avidity as it cools; and it retains the property if cooled by immerſion in mercury, the abſorption being equally conſiderable when it is afterwards expoſed to the air.

— reſiſts heat, and abſorbs elaſtic fluids:

The diſpoſition to be burned, which in the ancient theory is ſuppoſed to conſiſt in the giving out of phlogiſton, and in the modern theory in the abſorption

— exceedingly combuſtible.

ſorption of vital air, is ſo great in charcoal, that it performs the reverſe of combuſtion with a great variety of ſubſtances. Thus it converts the vitriolic acid into vitriolic air, by augmenting the proportion of ſulphur; and it is ſtrongly acted on by the nitrous acid, much nitrous air being extricated at the ſame time. The rapidity with which the nitrous acid acts upon perfectly dry charcoal, has been already mentioned. In either of theſe proceſſes, the acid either combines ſuddenly with the phlogiſton of the charcoal, or the vital air of the acid combines with the charcoal itſelf, conſidered as a ſimple ſubſtance.

Charcoal.

Page 165.

The moſt violent combuſtion of nitre with charcoal, in which the acid is entirely decompoſed, and gives out phlogiſticated air, may be explained in the ſame way by each theory.

Solubility of charcoal.

Alkalis diſſolve charcoal in the dry way; and liver of ſulphur combines very readily with it, either in the dry or humid way. All the metallic ſubſtances hitherto known are leſs combuſtible than charcoal, and conſequently are revived, or reduced to the metallic ſtate, by being heated with this ſubſtance. This, in the ancient theory, denotes that all the metals attract phlogiſton more ſtrongly than charcoal does; but in the new theory the effect is aſcribed to the ſtronger attraction of charcoal, which deprives all metallic calces of the vital air which combined with them during their calcination.

Revivification.

Obſervation.

An important conſequence ſeems to follow from this circumſtance; namely, that there may exiſt many metallic ſubſtances whoſe combuſtibility may be greater than that of charcoal; and which conſequently are unknown to us as ſuch, becauſe we poſſeſs no means of reducing them. Thus the alkalis and earths may conſiſt of peculiar combuſtible or metallic ſubſtances, either dephlogiſticated, or combined with vital air, by an union which the art of chemiſtry has not yet found means to break.

Combuſtion of charcoal.

When charcoal is expoſed to heat in open veſſels, it burns with a light flame, nearly tranſparent, emitting very little light, and no ſmoke. The reſidue conſiſts of a ſmall quantity of aſhes, which contain fixed alkaline and neutral ſalts. The fixed vegetable alkali is obtained from the aſhes of various plants, under the name of pot-aſh or pearl-aſh, and is not eaſily purified from the neutral ſalts it may be contaminated with. Mineral alkali is obtained by incineration only from marine plants. The neutral ſalts found in the aſhes of vegetables are vitriolated tartar, Glauber's ſalt and ſelenite, common ſalt, and ſalt of Sylvius. Calces of iron and of mangancſe, with an earthy ſubſtance, compoſe the inſoluble reſidue. What this earthy ſubſtance is has not been determined; but it moſt probably conſiſts of ſome inſoluble earthy ſalt, ſuch as phoſphorated lime.

Reſidual ſalts.

CHAP. VII.

CONCERNING FERMENTATION IN GENERAL.

FERMENTATION.

The ſpontaneous decompoſition of vegetables.

THE word Fermentation, in an enlarged ſenſe, is uſed to denote that change of the principles of organic bodies, which begins to take place ſpontaneouſly as ſoon as their vital functions have ceaſed, and by which they are at length reduced to their firſt principles. This has been diſtinguiſhed into three ſtages; the vinous or ſpirituous, the acid or acetous, and the putrid fermentation; which are ſo called from the principal products obtained during their action. All organized bodies are not ſubject to the three degrees of fermentation. It is aſcertained almoſt beyond a doubt that the vinous fermentation takes place only in ſuch bodies as contain ſaccharine juices. In this the moſt remarkable product is a volatile, colourleſs, light, inflammable fluid, which mixes with water in all proportions, and is called ardent ſpirit. The acetous fermentation is diſtinguiſhed by the product known by the name of vinegar, which is the leaſt deſtructible of the vegetable acids. It does not appear, however, that fermentation is abſolutely neceſſary for the production of this acid, as there are other chemical means by which it may be obtained, or produced. In the putrid fermentation, bodies appear to be reduced into their moſt ſimple parts. Volatile alkali is the product which has been remarked as the chief in this proceſs,

Three ſtages of fermentation:

— vinous:

— acetous:

Page 449.

— putrid:

FERMENTATION.

Stages of fermentation.

proceſs, and is no doubt produced by the combination of inflammable and phlogiſticated air, which fly off together. The acetous, like the vinous fermentation, is confined to vegetable ſubſtances; but the putrefactive proceſs is moſt eminently perceived in animal bodies. Theſe either putrefy immediately; or, if the putrefaction be preceded by either of the other ſtages, their duration is too ſhort to be perceived. It is conſidered as an eſtabliſhed fact, that the three ſtages of fermentation always follow in the ſame order, in ſuch bodies as are ſuſceptible of them all; the vinous coming firſt, which is followed by the acetous and the putrefactive proceſſes.

Conditions or circumſtances requiſite to the progreſs of fermentation.

The ſpontaneous decompoſition of bodies is greatly retarded by extreme cold, by ſudden drying of the parts, or by preſervation in cloſed veſſels. The two firſt circumſtances neceſſarily retard the chemical effects, by depriving the parts of that fluidity which is almoſt indiſpenſably neceſſary in chemical proceſſes. It will eaſily be underſtood that the third circumſtance will retard the ſpontaneous decompoſition of bodies, when it is conſidered that the atmoſphere itſelf is the ſolvent and receptacle of many of the component parts of bodies with which it is diſpoſed to combine. In well-cloſed veſſels, the parts of organized bodies which are diſpoſed to fly off in the elaſtic ſtate, are prevented from eſcaping; and ſuch parts as might form new combinations, by abſorbing either the contents, or component parts of the atmoſphere, are prevented for want of a free communication. The three conditions for the accompliſhment of fermentation are, therefore, fluidity or moiſture, moderate heat or a due temperature, and the acceſs of air: and the fermentation will likewiſe be modified according to the various component parts of bodies.

Vinous fermentation deſcribed, as it takes place in ſugar and water.

In deſcribing the vinous decompoſition of vegetables, it will be of advantage to attend to that of mere ſugar and water; the phenomena in theſe being more diſtinct, becauſe leſs modified by foreign admixture. If a conſiderable quantity of water, holding in ſolution about one third of its weight of ſugar, be expoſed to the air at the temperature of about 70 degrees, after the addition of a ſmall quantity of yeaſt, it ſoon undergoes a remarkable change. In the courſe of a few hours the fluid becomes turbid and frothy; bubbles of fixed air are diſengaged, which riſe and break at the ſurface. The diſengagement becomes more and more abundant; mucilage is ſeparated, part of which ſubſides to the bottom; and part, expanded into froth by the elaſtic fluid, forms yeaſt. During the courſe of ſeveral days, theſe effects gradually come to their height, and diminiſh again; after which they proceed very ſlowly, but are long before they entirely ceaſe. The fermented liquor has no longer the ſweet taſte it had before, but becomes briſk and lively, with a pungent ſpirituous flavour. Its ſpecific gravity likewiſe is conſiderably leſs than before; and, when expoſed to diſtillation, it affords a light inflammable ſpirit. The quantity of ardent ſpirit which any fermented liquor will produce, is thought to follow ſome proportion of the change its ſpecific gravity undergoes in fermentation; but the truth

Yeaſt.

Inflammable ſpirit.

FERMENTATION.

truth of this has not been clearly aſcertained *. Wine, cyder, and beer, are well-known liquors of this kind.

Acetous fermentation.

It is uſual to put fermented liquors into caſks before the vinous fermentation is completely ended; and in theſe cloſed veſſels it goes on for many months. But if the fermentative proceſs be ſuffered to proceed in open veſſels, more eſpecially if the temperature be raiſed to 90 degrees, the acetous fermentation comes on. In this the vital part of the air is gradually abſorbed; and the more ſpeedily, in proportion as the ſurfaces of the liquor are oftener changed by lading it from one veſſel to another. The uſual method conſiſts in expoſing the fermented liquor to the air in caſks, placed ſo that the ſun may ſhine on them; which ſeems to be of advantage, by raiſing the temperature of the liquor. By this abſorption of vital air, the inflammable ſubſtance becomes converted into an acid. If the liquid be then expoſed to diſtillation, pure vinegar comes over, inſtead of ardent ſpirit.

Putrefaction.

When the ſpontaneous decompoſition is ſuffered to proceed beyond the acetous proceſs, the vinegar gradually becomes viſcid and foul; air is emitted, with an offenſive ſmell; volatile alkali flies off; an earthy ſediment is depoſited; and the remaining liquid, if any, is mere water. This is the putrefactive proceſs.

Though fermentation is much better underſtood at preſent, in conſequence of modern reſearches into the

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* Richardſon on Brewing.

The effect of yeaſt in fermentation.

nature of elaſtic fluids, than it formerly was, it ſtill remains an intereſting object of reſearch. It is not clearly aſcertained what the yeaſt or fermented matter performs in this operation. It ſeems probable that the fermentative proceſs, in conſiderable maſſes, would be carried on in ſucceſſion, from the ſurface downwards; and would perhaps be completed in one part of the fluid before it was perfectly begun in another part, if the yeaſt, which is already in a ſtate of fermentation, did not occaſion the proceſs to begin in every part of the fluid at once. Much remains to be done towards aſcertaining the arrangement and quantity of the component parts of ardent ſpirit: and the theory of fixed air, with the identity of inflammable airs, muſt be aſcertained, before any decided reaſoning can be adopted on this head. It ſeems however that inflammable air, in combination with fixed air in certain proportions, forms ardent ſpirit; that a greater proportion of vital air converts it into vinegar; and that, in the putrefactive proceſs, the inflammable air, the fixed air, and the vital air, are ſeparated from each other, and fly off in the elaſtic ſtate.

Component parts of ardent ſpirit, &c.

Tartar.

In the fermentation of wine, the tartar, which probably exiſted for the moſt part ready formed in the juice of the grape, is ſeparated, and exhibits the properties which have been already deſcribed in treating of that ſubſtance.

Bread.

The fermentation of bread by leaven is thought to be of a different nature from the vinous fermentation. In this the mucilage of the corn is not previouſly brought into the ſaccharine ſtate. It quickly becomes ſour, FERMENTATION. Bread.

ſour, if the proceſs be not ſtopped by baking; in which particular, the fermentation ſeems to be of the acetous kind. The development of fixed air divides the dough into thin parts, which are more effectually and better baked than they could have been in the ſolid conſiſtent maſs. When bread is fermented by means of yeaſt, the proceſs appears to be of a ſaccharine or vinous nature.

CHAP. VIII.

CONCERNING VINOUS FLUIDS AND ARDENT SPIRIT.

VINOUS FLUIDS.

The making of wine from grapes.

FROM the habits of ſociety, the making of wine, beer, and ardent ſpirits, is become an object of conſiderable importance. Wine is the expreſſed juice of the grape which has undergone the firſt ſtage of fermentation. In this, which in general appears to be the beſt kind of fermented liquor, there are great differences, which depend no leſs on the kind and quality of the fruit than on the proceſs of manufacturing. If the fruit be gathered unripe, the juice will abound with acid, and the wine will be thin and ſharp; but, if the fruit be ripe, it will contain much ſaccharine juice, and the wine will be ſweeter. If the wine be caſked in an early ſtage of the fermentation, much of the ſugar will remain undecompoſed, and the wine will be ſweeter on that account, eſpecially if the fermentation be checked by a conſiderable degree of cold; but, on the contrary, when the progreſs of the fermentation is only impeded by the coercion of the veſſel, which prevents the eſcape of the fixed air, a ſlight increaſe of temperature, ſuch as that of a room in a dwelling-houſe compared with the temperature of a cellar, will cauſe it to proceed with great rapidity as ſoon as the veſſel is opened. Wines in this ſtate are very briſk and lively, from the predominating acidity of the fixed air, which is haſtily diſengaged.

The malting of barley:

Beer is the wine of grain. Malt is uſually made of barley. This grain is ſteeped for two or three days in water till it ſwells, becomes ſomewhat tender, and tinges the water of a bright reddiſh brown colour. The water being then drained away, the barley is ſpread about two feet thick upon a floor, where it heats ſpontaneouſly, and begins to grow, by firſt ſhooting out the radicle. In this ſtate the germination is ſtopped, by ſpreading it thinner, and frequently turning it over for two days; after which, it is again made into an heap, and ſuffered to become ſenſibly hot, which uſually happens in little more than a day. Laſtly, it is conveyed to the kiln, where, by a gradual and low heat, it is rendered dry and criſp. This is malt; and its qualities differ according as it is more or leſs ſoaked, drained, germinated, dried, and baked. In this, as in other manufactories, the intelligent operators often make a myſtery of their proceſſes, from views of profit; and others pretend to peculiar ſecrets, who really poſſeſs none.

— of Indian corn.

Indian corn, and probably all large grain, require to be ſuffered to grow into the blade, as well as root, before it is fit to be made into malt. For this purpoſe, it is buried about two or three inches deep in the ground, and covered with looſe earth; and in ten or twelve days it ſprings up. In this ſtate it is taken up and waſhed, or fanned, to clear it from its dirt, and then dried in the kiln for uſe.

Brewing of beer.

Beer is made from malt previouſly ground, or cut in pieces by a mill. This is placed in a tun, or tub, with a falſe bottom; hot water is poured upon it, and the whole ſtirred about with a proper inſtrument. The temperature of the water in this operation, called maſhing, muſt not be equal to boiling; for in that caſe the malt would be converted into a paſte, from which the impregnated water could not be ſeparated. After the infuſion has remained for ſome time upon the malt, it is drawn off, and is then diſtinguiſhed by the name of ſweet wort. By one or more ſubſequent infuſions of water, a quantity of weaker wort is obtained, which is either added to the foregoing, or kept apart, according to the intention of the operator. The wort is then boiled with hops, which give it an aromatic bitter taſte, and are ſuppoſed to render it leſs liable to be ſpoiled in keeping; after which, it is cooled in ſhallow veſſels, and ſuffered to ferment, with the addition of a proper quantity of yeaſt. The fermented liquor is beer; and differs greatly in its quality, according to the nature of the grain, the malting, the maſhing, the quantity and kind of the hops and the yeaſt, the purity or admixtures of the water made uſe of, the temperature and viciſſitudes of the weather, &c.

Brewing of beer.

Beſides wine and beer, which are made immediately from vegetables; other fermented liquors, containing ardent ſpirit, are made from honey and from mare's milk. The former is called metheglin; and the latter, which is made by the Tartars, koumiſs *. This laſt is made by agitating the milk, at the time when its parts begin to ſeparate, by a fermentation productive of a peculiar acid, called the acid of milk, hereafter to be deſcribed.

Metheglin and koumiſs.

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* Grieve, in the Edinburgh Tranſactions, vol. i. p. 181.

ARDENT SPIRIT.

Product of vinous liquors by diſtillation.

In order to obtain ardent ſpirit, nothing more is neceſſary than to expoſe wine, beer, or any other fermented vinous liquid, to diſtillation; and the product which comes over is the ardent ſpirit itſelf, contaminated with eſſential oil. If this be rectified by a ſecond diſtillation, it becomes much purer. The moſt volatile part riſes firſt, and is of a leſs ſpecific gravity than that which comes over afterwards.

Reſidue.

The reſidue, after the diſtillation of ardent ſpirit from wine, is of a deep colour, a rough acid taſte, and depoſits cryſtals of tartar. The colouring matter is ſoluble in ardent ſpirit. So that it appears, from this imperfect analyſis, that wine conſiſts of water, ardent ſpirit, colouring matter of a reſinous nature, ſugar, tartar, and tartareous acid, and an aromatic principle.

Strength of ardent ſpirit determined by M. Bories.

The ſtrength or purity of ardent ſpirit is aſcertained from its ſpecific gravity; for the addition of water renders it heavier. According to M. Bories, whoſe Memoir, publiſhed at Montpellier in the year 1774, obtained the prize propoſed by the ſtates of Languedoc in 1772, the ſpecific gravity of rectified ardent ſpirit repeatedly poured on dry ſalt of tartar till it would no longer diſſolve or liquefy it, was found by many experiments to be as follows:

Reaumur's Therm. + 10° = 820 $\frac{2900}{5055}$
15° = 817 $\frac{65}{5055}$
20° = 813 $\frac{2284}{5055}$

The ſpecific gravities of mixtures, by meaſure, of the foregoing ſpirit with diſtilled water, were as follows:

Specific gravities of various mixtures of water and ſpirit.

Temperature + 15° Reaumur.

Spirit	10	Water	0	Specific	gravity	$817\frac{65}{5055}$
	9	—	1	—	—	$844\frac{3580}{5055}$
	8	—	2	—	—	$869\frac{4705}{5055}$
	7	—	3	—	—	$893\frac{1895}{5055}$
	6	—	4	—	—	$915\frac{925}{5055}$
	5	—	5	—	—	$934\frac{3630}{5055}$
	4	—	6	—	—	$951\frac{3695}{5055}$
	3	—	7	—	—	$965\frac{1925}{5055}$
	2	—	8	—	—	$976\frac{1320}{5055}$
	1	—	9	—	—	$987\frac{715}{5055}$
	0	—	10	—	—	1,000

Obſervations.

Upon the above experiments, which are among the moſt accurate we poſſeſs *, it may be obſerved, that the firſt term, or pure ſpirit, ought to be obtained with an alkali perfectly mild, or ſaturated with fixed air; becauſe, otherwiſe, ſolution and combination of the alkali with the ſpirit might take place. By diſtillation of twenty meaſures of the beſt ardent ſpirit of the ſhops, whoſe ſpecific gravity was 0.836 over a lamp in glaſs veſſels, I found the firſt meaſure which came over had a ſpecific gravity of 820, at the temperature of 71° Fahrenheit; which anſwers to 17⅕ of Reaumur. This is the ſtrongeſt ſpirit mere diſtillation can afford. When ſtrong ardent ſpirit is added to water, a conſiderable heat is produced, a few bubbles of air are emitted, the mixture contracts in its dimenſions, and acquires a greater ſpecific gravity than would have been deduced by computation.

Strongeſt ardent ſpirit by mere diſtillation.

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* See a very valuable ſet of experiments on this ſubject by Mr. Gilpin; of which Dr. Blagden has made a report in the Phil. Tranſ. lxxx. 321.

ARDENT SPIRIT.

Requiſites or deſiderata to aſcertain the ſtrength of ſpirit.

It is by no means an eaſy undertaking to determine the ſtrength or relative value of ardent ſpirit, even with ſufficient accuracy for commercial purpoſes. The following requiſites muſt be obtained before this can be well done: The ſpecific gravity of a certain number of mixtures of ardent ſpirit and water muſt be taken ſo near each other, as that the intermediate ſpecific gravities may not perceptibly differ from thoſe deduced from the ſuppoſition of a mere mixture of the fluids: the expanſions, or variations of ſpecific gravity, in theſe mixtures, muſt be determined at different temperatures: ſome eaſy method muſt be contrived of determining the preſence and quantity of ſaccharine or oleaginous matter which the ſpirit may hold in ſolution, and the effect of ſuch ſolution on the ſpecific gravity: and, laſtly, the ſpecific gravity of the fluid muſt be aſcertained by a proper floating inſtrument with a graduated ſtem, or ſet of weights; or, which may be more convenient, with both.

Phial proof.

The ſtrength of brandies in commerce is judged by the phial, or by burning. The phial proof conſiſts in agitating the ſpirit in a bottle, and obſerving the form and magnitude of the bubbles, which are larger the ſtronger the ſpirit. Theſe probably depend on the ſolution of reſinous matter from the caſk, which is taken up in greater quantities, the ſtronger the ſpirit. It is not difficult however to produce this appearance, by various ſimple additions to weak ſpirit.—The proof by burning is alſo fallacious; becauſe the magnitude of the flame, and quantity of reſidue, in the ſame ſpirit, vary greatly with the form of the veſſel it is burned

Proof by burning.

burned in. If the veſſel be kept cool, or ſuffered to become hot, if it be deeper or ſhallower, the reſults will not be the ſame in each caſe. It does not follow, however, but that manufacturers and others may in many inſtances receive conſiderable information from theſe ſigns, in circumſtances exactly alike, and in the courſe of operations wherein it would be inconvenient to recur continually to experiments of ſpecific gravity.

Characters and component parts of ardent ſpirit:

The moſt remarkable characteriſtic property of ardent ſpirit, is its ſolubility or combination in all proportions with water; a property poſſeſſed by no other combuſtible ſubſtance. When it is burned in a chimney which communicates with the worm-pipe of a diſtilling apparatus, the product which is condenſed is found to conſiſt of water, which exceeds the ſpirit in weight about one eighth part. If ardent ſpirit be burned in cloſed veſſels with vital air, the product is found to be water and fixed air. Whence it is inferred, that ardent ſpirit conſiſts of inflammable air, united either to fixed air, or its acidifiable baſe; and that the vital air, uniting on the one part with inflammable air, forms water; and, on the other, with the baſe of the fixed air, and forms that acid *.

— its uſes and combinations.

A conſiderable number of the uſes of this fluid, as a menſtruum, have already paſſed under our obſervation. The mutual action between ardent ſpirit and

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* For an account of theſe experiments, and the precautions neceſſary to be attended to in making them, conſult the Memoirs of M. Lavoiſier, in the Memoirs of the Royal Academy at Paris for 1781 and 1784.

acids,

Mutual action of ardent ſpirit and ſalts:

acids, produces a light, volatile and inflammable oil, called ether. Pure alkalis unite with ſpirit of wine, and form alkaline tinctures. Few of the neutral ſalts unite with this fluid, except ſuch as contain the volatile alkali. The mild fixed alkalis, or combinations of alkali and fixed air, are not ſoluble in it. From the ſtrong attraction which exiſts between ardent ſpirit and water, it unites with this laſt in ſaline ſolutions, and in moſt caſes precipitates the ſalt. This is a pleaſing experiment, which never fails to ſurpriſe thoſe who are unacquainted with chemical effects. If, for example, a ſaturated ſolution of nitre in water be taken, and an equal quantity of ſtrong ſpirit of wine be poured upon it, the mixture will conſtitute a weaker ſpirit, which is incapable of holding the nitre in ſolution; it therefore falls to the bottom inſtantly, in the form of minute cryſtals. Among the neutral ſalts which are ſoluble in ſpirit of wine, the deliqueſcent earthy ſalts ſtand firſt. Moſt ammoniacal ſalts are ſoluble in this menſtruum; and in general it combines more readily with ſuch as have their acid leſs adherent to the neutralizing baſe.

— and ſulphur:

Sulphur does not appear to be acted on more ſtrongly by ardent ſpirit than by water. If ſulphur in ſublimation meet with the vapour of ſpirit of wine, a very ſmall portion combines with it, which communicates an hepatic odour to the fluid. The increaſed ſurface of the two ſubſtances appears to favour the combination.

— and phoſphorus.

Phoſphorus is ſparingly ſoluble in ardent ſpirit, but in greater quantity by heat than in the cold. The addition of water to this ſolution affords an opake milky fluid which gradually becomes clear by the ſubſidence of the phoſphorus.

— and earths.

Earths ſeem to have ſcarce any action upon ardent ſpirit. Quick-lime however produces ſome alteration in this fluid, by changing its flavour, and rendering it of a yellow colour. A ſmall portion is probably taken up.

Spirituous ſolutions.

Soaps are diſſolved with great facility in ardent ſpirit, with which they combine more readily than with water. None of the metals, nor their calces, are acted upon by this fluid. Reſins, eſſential oils, camphor, bitumen, and various other ſubſtances, are diſſolved with great facility in ardent ſpirit, from which they may be precipitated by the addition of water.

CHAP. IX.

CONCERNING THOSE INFLAMMABLE FLUIDS WHICH ARE PRODUCED BY THE ACTION OF ACIDS UPON SPIRIT OF WINE, AND ARE KNOWN BY THE NAME OF ETHER.

ETHER. The making of vitriolic ether.

WHEN ſtrong vitriolic acid is poured upon an equal meaſure of rectified ſpirit of wine, the two fluids unite together, with a hiſſing noiſe and the production of heat, at the ſame time that a fragrant vegetable ſmell is emitted, reſembling that of apples: it is more advantageous, however, to add the acid in ſo gradual a manner as to produce little or no heat. If the mixture be made in a retort, and then expoſed to diſtillation by a well-regulated heat in a ſand-bath, a large receiver being adapted, and kept cool by immerſion in water, or by the frequent application of wet cloths, the volatile products may be ſafely condenſed. Spirit of wine of a fragrant ſmell comes over firſt, and is followed by the ether, as ſoon as the fluid in the retort begins to boil. At this period the upper part of the receiver is covered with large diſtinct ſtreams of the fluid, which run down its ſides. After the ether has paſſed over, volatile ſulphureous acid ariſes, which is known by its white fumes and peculiar ſmell. The receiver muſt now be removed, and another ſubſtituted in its place, care being taken to avoid breathing the penetrating fumes of the acid.

The

Diſtillation of vitriolic ether.

The fire muſt at the ſame time be moderated, becauſe the reſidue in the retort is diſpoſed to ſwell. A light yellow oil, called ſweet oil of wine, comes over after the ether, and this is ſucceeded by black and foul vitriolic acid. The reſidue varies in its properties according to the management of the heat. If the fire be much increaſed towards the end of the proceſs, the volatile vitriolic acid which comes over will be mixed with vinegar. If the remaining fluid contained in the retort, after the ether has paſſed over, be not urged farther, it may be made to afford more ether, by the addition of one-third of very ſtrong ardent ſpirit; and this may be repeated ſucceſſively, until near twice the quantity of the ſpirit originally made uſe of has been added.

Rectification.

Ether of the firſt diſtillation is not pure, but contains ſpirit of wine and ſulphureous acid, which may be ſeparated by the addition of a fixed alkali, and rectifying with a gentle heat. In this rectification, as in all others, the firſt products are the pureſt.

Characters.

Vitriolic ether is one of the lighteſt and moſt volatile of all denſe and unelaſtic fluids. Its diſſipation into the air is ſo ſudden as to produce an extreme degree of cold. It is highly inflammable, and burns with a more luminous flame, and emits more ſmoke than ardent ſpirit.

Solubility in water.

About ten times its weight of water is ſufficient to diſſolve it. A ſmall proportion of water renders unrectified ether more pure, becauſe it combines with the ardent ſpirit and acid it may contain; but there is reaſon to think, on the other hand, that the ether diſſolves, and combines with part of the water.

Little

ETHER.

Combinations of vitriolic ether.

Little is known of the action of this fluid upon ſaline ſubſtances. Lime and fixed alkalis do not ſeem capable of uniting with it. Cauſtic volatile alkali combines with it in all proportions; vitriolic acid unites with it, and extricates heat, and from this combination ſweet oil of wine may be obtained by diſtillation. Nitrous acid effervefces with ether, and renders it more oily. It diſſolves camphor very plentifully.

Method of preparing nitrous ether.

The nitrous acid acts very rapidly and powerfully upon ardent ſpirit, with which it forms a combination, poſſeſſing properties ſimilar to thoſe of the vitriolic ether. The combination takes place without the aſſiſtance of heat, and with ſuch facility, that it is even neceſſary to add the acid by degrees, and to uſe management for the purpoſe of preventing an exploſion, which might ariſe from the heat generated by the mixture. For this purpoſe ſix ounces of highly rectified ſpirit of wine are put into a bottle capable of containing a pound of water, and immerſed in a tub of very cold water, in which it will be advantageous to put three or four pounds of ice broken ſmall. Upon the ſpirit in this ſituation, and kept continually agitated, four ounces of ſpirit of nitre, of the ſpecific gravity of 1.5, are to be poured, in four or five ſucceſſive portions. As ſoon as the mixture is completed, the bottle muſt be cloſed with a good cork, ſecured with leather and packthread, or wire; and the whole muſt be left in a place where it may remain undiſturbed; no other attention being neceſſary than that of renewing the water, from time to time, as it may become heated. In the courſe of two or three hours, Methods of preparing nitrous ether.

the tranſparency of the fluid becomes troubled, by an infinity of drops of ether, which are diſengaged from every part of its volume. This ether gradually riſes to the ſurface; and at the end of twenty-four hours it may be ſeparated from the reſt of the liquor by means of a funnel. In opening the phial, it is neceſſary firſt to pierce the cork with a pointed inſtrument, in order that a quantity of elaſtic fluid may eſcape, which might otherwiſe ſuddenly follow the cork, and carry part of the fluid along with it. The quantity of ether obtained in this manner will be about four ounces.

Characters.

Nitrous ether in this ſtate reſembles vitriolic ether in its ſmell, but it is ſtronger and leſs agreeable. Its colour is a light orange; and a portion of the fluid takes the elaſtic form, and eſcapes with efferveſcence whenever the bottle, which contains it, is opened. This ether appears to contain a portion of uncombined acid, upon which theſe phenomena probably depend. It muſt be rectified with a ſmall addition of alkali, during which operation it loſes near half its weight. The rectified nitrous ether burns with a flame rather more luminous than that of vitriolic ether, at the ſame time that it affords a ſomewhat larger portion of ſmoke, and leaves a black trace behind it. In other reſpects it ſeems nearly to reſemble the vitriolic ether.

Nitrous ether may be made with leſs danger, if the acid be diluted, and the quantity of ſpirit duly proportioned. It may alſo be had by diſtillation of a mixture of the two fluids, in the ſame manner as the vitriolic ether; but in this caſe it is requiſite that the receiving veſſels ſhould be uncommonly large, and that

ETHER.

Methods of preparing nitrous ether.

that every precaution ſhould be taken to prevent their flying in pieces by the force of the elaſtic product which eſcapes: and, upon the whole, it does not ſeem probable that any ordinary degree of precaution would be ſufficient to inſure the operator from danger in this diſtillation. One very eſſential circumſtance conſiſts in uſing the acid in a diluted ſtate.—Nitrous ether has alſo been made by leſs direct proceſſes. If a due proportion of nitre and vitriolic acid be ſucceſſively put into a tubulated retort, the nitrous acid begins to be diſengaged; and, if ſpirit of wine be added to this mixture, nitrous ether comes over. Some degree of precaution is neceſſary in this proceſs; and it might be doubted whether part of the ether which comes over might not have been formed by the vitriolic acid, if moſt of the difficulties were not removed by the uſe of the apparatus, fig. 22. If the tube E be immerſed in a bottle containing highly rectified ſpirit of wine, and the nitrous acid be diſtilled from a quantity of nitre equal in weight to twice the ſpirit of wine, together with as much concentrated vitriolic acid as is equal to half the weight of the nitre; the firſt receiver D will, at the end of the operation, contain fuming nitrous acid; the remote bottle E will contain an ethereal liquor; and the reſidue will be vitriolated tartar. The ethereal ſpirit of wine may then be diſtilled, and the firſt two-thirds of the product reſerved. This reſerved product muſt be diſtilled with one-fifth of its weight of ſmoking nitrous acid, added by degrees to the liquor, in a tubulated retort, by means of a long-necked funnel. Two thirds of this product only are to be taken; which, being rectified

Nitrous ether.

fied from pot-aſh, afford at firſt a quantity of very pure nitrous ether, equal to about one twelfth of the ſpirit made uſe of; and three fourths of the reſt being diſtilled over, conſiſt of a leſs perfect ether, or mineral anodyne liquor. The reſidues of the diſtillations conſiſt of dulcified ſpirit of nitre *.

It is proper, even here, to take notice that all mixtures of the nitrous acid and ardent ſpirit require to be made very gradually, and with great caution, for fear of exploſions.

The reſidue, after diſtillation of nitrous ether, is found, in ſome proportions of the materials and management of the proceſs, to contain no nitrous acid, but an imperfect vinegar, and the acid of ſugar or ſorrel.

Method of preparing marine ether.

The marine acid cannot be combined with ſpirit of wine in the direct way. There are many indirect methods, which conſiſt in applying the dephlogiſticated or aërated marine acid to ardent ſpirit. If to four ounces of common ſalt, and two ounces of pulverized manganeſe, there be added two ounces of concentrated vitriolic acid, and ſix ounces of the pureſt ardent ſpirit, and the whole be expoſed to diſtillation by a gentle heat, the marine acid will firſt riſe, ſomewhat changed; and, after a conſiderable portion has paſſed over, it muſt be poured back upon the reſiduum, and diſtilled afreſh. In this diſtillation, nearly the half which firſt comes over will be dulcified ſpirit of ſalt; and the greateſt part of the other half, marine ether, which may be ſeparated from the reſt by the addition of water.

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* De la Planche, quoted by Fourcroy, iv. 252.

Marine ether is very tranſparent and volatile, and has nearly the ſame ſmell as the vitriolic ether. It burns like that fluid, and affords a ſmoke, with a ſuffocating ſmell.

Methods of preparing acetous ether.

It is doubted whether any ethereal fluid can be obtained by the direct union of acetous acid and ardent ſpirit. If equal parts of the ſtrongeſt acetous acid and ardent ſpirit be mixed together, and kept for ſome days in a well-ſtopped glaſs, and the mixture be then expoſed to diſtillation by a gentle heat, the firſt half which comes over will, it is ſaid, conſiſt of an ethereal fluid, from which the ether may be ſeparated, by the addition of a ſixteenth part of vegetable alkali, diſſolved in four times its quantity of water. The ether immediately riſes to the top, and commonly amounts to one half of the quantity of the ardent ſpirit made uſe of. To the vinegar that remains in the retort half the quantity of ardent ſpirit may be added, by which ſtill more of the ether may be obtained. The moſt certain and incontrovertible method, however, appears to conſiſt in forming the union between the ſpirit and acid by indirect means. This may be done by decompoſing ſome acetous ſalt, by the addition of a mineral acid, while ardent ſpirit is preſent. Thus, if an ounce of alkali ſaturated with vinegar be diſſolved in three ounces of ſpirit of wine, and a little more of any mineral acid than is ſufficient to ſaturate the alkali be added, and the maſs be then diſtilled, acetous ether will be obtained. Or if eight ounces of ſugar of lead be gently dried, to deprive it of its water of cryſtallization, which amounts to rather more than one fourth of its weight; if in this ſtate it be put into a glaſs retort, and a mixture of five ounces of vitriolic acid, and eight ounces of ſpirit of wine, be poured on it, and the whole expoſed to diſtillation by a very gentle heat, the firſt ounce that paſſes over will conſiſt of dulcified acetous acid, the next ounce will be almoſt all ether, and the whole quantity of ether produced will be near four ounces.

Acetous ether.

Acetous ether is not nearly ſo volatile as the nitrous or vitriolic; it burns with a blue flame, like ſpirit of wine.

Ligneous ether.

The empyreumatic acid of wood likewiſe affords an ether. For this purpoſe it may be diſtilled from beech, rectified a ſecond time, and then ſaturated with alkali. Three pounds of the acid require about five ounces of alkaline ſalt. By evaporation to dryneſs, with ſubſequent ſolution, filtration, and evaporation, three ounces and a quarter of neutral ſalt are obtained. The concentrated acid of wood may be diſengaged from this by diſtillation with two ounces of vitriolic acid; and the quantity of acid of wood thus obtained weighs an ounce and three quarters. By mixing this with an equal quantity of pure ardent ſpirit, and diſtilling it in a ſmall retort, near two ounces and a quarter of ether are obtained.

Saccharine ether.

Equal parts of ſalt of ſorrel and ardent ſpirit afford about one fifth of their weight of ether. The acid of ſugar likewiſe affords an ether with ſpirit of wine, which can hardly be ſuppoſed to differ from the foregoing, as the two ſalts are the ſame.

Phoſphoric ether.

The acid of phoſphorus does not produce an ethereal combination by direct diſtillation with ardent ſpirit: but it is ſaid that the combination takes place with a due mixture of ardent ſpirit, vitriolic acid, and microcoſmic ſalt; the phoſphoric acid being expelled from its baſe, probably in a more dephlogiſticated ſtate than when obtained by ſuffering phoſphorus to deliqueſce in the air.

Ether produced by acid of ants:

The acid of ants produces an ether, with ſpirit of wine, by ſimilar treatment.

— by acid of benzoin.

Acid of benzoin does not produce ether by ſimple ſolution, and ſtanding in ſpirit of wine; but, when one part of the acid of benzoin is diſtilled with three parts of ardent ſpirit, and one half part of common marine acid, the pure ſpirit comes firſt over, and afterwards an ethereal combination, one part of which floats upon water, and the other ſinks to the bottom. This is not more volatile than acetous ether, and burns with a bright flame and ſmoke.

General obſervations.

The converſion of ardent ſpirit into ether, is a proceſs concerning which much remains to be explained. It was formerly thought that the acid did nothing more than deprive the ſpirit of a quantity of water, which was before combined with it, and prevented its exhibiting oleaginous properties. It ſeems aſcertained however, at preſent, that all the ethers contain a portion of that peculiar acid, by whoſe action the ſpirit was changed; as may be ſhewn by ſuffering them to evaporate, or burning them away upon water. It appears therefore that the acid, or ſome of its component parts, combine either with the whole or part of the ardent ſpirit. Some chemiſts have with conſiderable probability aſſerted, that the baſis, or acidifiable principle, of the acid, combines with the ſpirit by the effect of a double affinity; ſo that

Theoretical obſervations.

that the vital air of the acid combines with a portion of acetous baſis exiſting in the ſpirit, and forms vinegar; another portion combines with the vegetable principles exiſting in ſuch a ſtate as to form the ſaccharine acid; and, laſtly, the acidifiable baſis itſelf, which gave out this vital air, is ſuppoſed to combine with the undecompoſed ſpirit, or vegetable inflammable matter, and riſe in the form of ether. In this view of the ſubject, the nitrous ether is more particularly attended to, and the inferences are extended to other ethers; and oils are ſuppoſed to conſiſt of vegetable inflammable matter, combined with the baſis of an acid *.

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* On Ethers, ſee Wiegleb's Chemiſtry, by Hopſon, p. 510, et ſeq.; Scheele's Eſſays, &c.

CHAP. X.

CONCERNING THE ACETOUS ACID.

ACETOUS ACID.

AS moſt of the compounded vegetable acids are convertible, by nitrous acid and by other means, into acid of ſugar, and this laſt into vinegar, it is evident that fermentation is only one of the proceſſes which change the principles of plants into this leaſt deſtructible of vegetable acids. All the vinegar however which is uſed in the common purpoſes of life, is obtained by fermentation. Crude vinegar contains not only that peculiar acid which is diſtinguiſhed by the name of acetous, but likewiſe tartar, oily matter, and frequently ſome of the acids of the fruits from which it may have been procured. It is uſual to purify it by diſtillation. The firſt product conſiſts of a watery fluid, of a lively and agreeable ſmell, though ſcarcely acid. Next follows the acetous acid, commonly called diſtilled vinegar, which has a peculiar ſmell, leſs agreeable than that of the crude vinegar. As the diſtillation proceeds, the volatile product becomes more and more acid, ſomewhat darker coloured, and of an empyreumatic ſmell. The reſidue, after the greateſt part of the fluid has been volatilized, has a deep browniſh red colour, is conſiderably acid, and depoſits a quantity of tartar. By diſtillation to dryneſs, it affords a reddiſh phlegm; more acid; an oil, at firſt light, and afterwards heavy; together with a ſmall quantity of volatile alkali: the reſidual coal contains

Crude vinegar.

Diſtilled vinegar, or acetous acid.

tains much fixed alkali. The quantity of acid product reſerved as diſtilled vinegar, is commonly about two thirds of the whole.

Concentration of vinegar by froſt.

Vinegar may be concentrated by froſt, which ſeparates its aqueous part. This proceſs is particularly applicable to crude vinegar; as, by this means, the grateful flavour, and peculiar properties, are preſerved. An ingenious method has been contrived for combining the two proceſſes of diſtillation and congelation, in concentrating and purifying vinegar. In this way, good wine vinegar is to be diſtilled on a water bath. It is eſſential to reſerve the phlegm, becauſe the moſt fragrant parts come over firſt, and are retained in this fluid. The diſtilled vinegar and phlegm being then expoſed to a freezing cold, and the ice taken out, a concentrated acid remains; which may be completely deprived of its extraneous and oily parts, by repeated rectifications on a water bath. At the beginning of the rectification, a very ſpirituous fluid paſſes over; which being ſeparated, and rectified by itſelf, yields a true and fine ether, of a very pleaſant ſmell, and immiſcible with water; which ether is to be added to the ſtrong and purified vinegar obtained by the repeated rectifications. The author of this method obſerves, that the peculiar and unpleaſant ſmell of diſtilled vinegar proceeds from ſome oily parts which paſs over in the diſtillation; and that, when theſe parts have been ſeparated by rectifying the acid concentrated by froſt, it again recovers the pleaſant ſmell of undiſtilled vinegar *.

The moſt advantageous method of concentrating vinegar.

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* Lowitz, in Crell's Annals, quoted by Keir in his Chemical Dictionary, page 32.

ACETOUS ACID.

Combinations of acetous acid:

Pure acetous acid enters into many combinations; and is recovered again by decompoſition, though ſeldom perhaps in its original ſtate. In many of its combinations it ſeems neceſſary that it ſhould become more ſtrongly acidified by attracting vital air from the atmoſphere, or from other bodies. This circumſtance has not been ſufficiently attended to, to admit of a proper diſtinction of every caſe in which it may, or may not, happen. We ſhall not therefore attempt to point them out, except incidentally, and where the facts are clear.

— with argillaceous earth:

The acetous acid unites with earth of alum, or argillaceous earth, in conſiderable quantity, and forms a whitiſh ſaline maſs, which is not cryſtallizable. There is however a diſagreement among practical chemiſts reſpecting this combination. Some aſſert that it takes place very ſparingly, and forms ſmall needled cryſtals. Theſe differences may probably depend on certain circumſtances relative to the edulcoration of the earth of alum, after it has been precipitated from its ſolution by an alkali.

— with calcareous earth:

Calcareous earth is readily diſſolved in the acetous acid, and forms a ſalt, the figure of whoſe cryſtals varies according to circumſtances. It is permanent in the air, unleſs the acid be in exceſs; in which caſe it deliqueſces. Its taſte is ſharp and bitter. When diſtilled without addition, the acid quits the earth, and appears in the form of an inflammable vapour, which condenſes into a reddiſh brown liquor; and, when rectified, is very volatile and inflammable.

The acetous acid forms a ſaline maſs by combination

tion with ponderous earth, which does not cryſtallize, but, if dried, attracts moiſture from the air.

Combination of acetous acid with magneſia:

Magneſian earth unites with acetous acid, and affords a very ſoluble ſalt; which, when perfectly ſaturated and evaporated, affords a viſcid maſs, reſembling gum water. Its taſte is ſweetiſh at firſt, but afterwards bitter; and it is ſoluble in ſpirit of wine. Mere heat diſſipates its acid, which may be obtained by diſtillation.

— with vegetable alkali. Foliated earth of tartar.

The combination of vegetable alkali with the acetous acid, produces the ſalt improperly called foliated earth of tartar. In the preparation of this ſalt, it is beſt to add an exceſs of acid. The evaporation muſt be carried to dryneſs on a water bath, in a glaſs or ſilver veſſel. This ſalt cannot eaſily be cryſtallized. Its taſte is penetrating, acrid, and urinous; heat decompoſes it: by diſtillation, it affords an acid phlegm, empyreumatic oil, volatile alkali, and much elaſtic fluid, conſiſting of fixed and inflammable air. The reſidual coal contains much vegetable alkali. If foliated tartar be decompoſed by the addition of vitriolic acid in diſtillation, the quantities being one part of the concentrated acid to two of the ſalt, in a tubulated retort, with a receiver, or apparatus of veſſels adapted, the acetous acid immediately riſes in the elaſtic form, with a ſtrong effervеſcence, and is condenſed in the receiver. This fluid is called radical vinegar, and its acid properties are more intenſe than thoſe of common acetous acid. It is highly probable that this augmentation of acidity is produced by the tranſition of vital air from the vitriolic acid to the acetous; perhaps with the contrary tranſition of phlogiſton.

Radical vinegar.

Combinations of acetous acid:

giſton. So that, while the acetous acid becomes more acidified, a portion of the vitriolic acid has its acidity diminiſhed, and is converted into ſulphureous acid, which comes over, and contaminates the product in the receiver.

— with mineral alkali:

The acetous acid unites perfectly with the mineral alkali, and forms a cryſtallizable permanent ſalt. The properties of the acetous ſalt of mineral alkali do not remarkably differ from thoſe of the foliated earth of tartar. By diſtillation with vitriolic acid, it affords a purer acetous acid than the foliated tartar does.

— with volatile alkali:

The ſalt formed by uniting acetous acid with volatile alkali, has been called ſpirit of Mindererus, or acetous ſal ammoniac. It does not eaſily cryſtallize; for which purpoſe it requires to be evaporated to the conſiſtence of ſyrup, and then expoſed to the cold. It ſoon attracts the moiſture of the air, and has a ſharp and burning taſte. This ſalt is decompoſable by heat; by lime and alkalis, which ſeize its acid; or by the mineral acids, which ſeize its baſe.

— with gold:

The acetous acid has no effect on gold in the metallic ſtate. When added to a ſolution of gold, it throws it down in the metalline form. The precipitate of gold, effected by a fixed alkali, becomes of a purple colour when digeſted with the common acetous acid. Radical vinegar diſſolves it.

— with ſilver.

Silver is not acted on by acetous acid; though the calces of this metal, obtained by an alkali from nitrous acid, are ſoluble.

Platina is likewiſe inſoluble in this acid; though its precipitate from aqua regia, by a fixed alkali, is ſoluble.

Acetous

Combination of acetous acid with mercury:

Acetous acid does not appear to be affected by mercury; but it diſſolves the mercurial calces. The cryſtals of this ſolution have a foliated appearance, reſembling that of the acid of borax.

— with lead: Page 270.

Lead is diſſolved with the greateſt facility by vinegar. The manufacture of ceruſe and ſugar of lead has before engaged our attention.

— with copper:

Copper is likewiſe ſoluble in vinegar, provided atmoſpheric air be preſent. The cryſtals of acetous acid and copper are improperly called diſtilled verdigriſe. It is from this ſalt that radical vinegar has uſually been diſtilled by mere heat, without addition. It is at firſt coloured by a portion of copper, which comes over; for which reaſon it muſt be rectified by a gentle heat. The reſidue, after diſtilling the acetous ſalt of copper, conſiſts of the metal in its reguline ſtate; whence it is ſeen that the vital air required to calcine the copper, comes over with the acid, which conſequently is in a dephlogiſticated or aërated ſtate. The laſt portion of radical acid which comes over is inflammable, and congealable by cold.

— with iron.

Iron is readily diſſolved by the acetous acid, with a ſlight effervescence, and the diſengagement of inflammable air. This ſolution depoſits much calx of iron by evaporation; and yields a few deliqueſcent cryſtals when cool. Very little action takes place between common vinegar and iron filings, unleſs by ſtanding; during which time, it is probable that the action of the air may contribute in ſome degree to the effect.

Compare page 309.

— with tin.

When tin is digeſted with the acetous acid, a ſmall portion appears to be taken up. The acid becomes

turbid,

turbid, acquires a metallic taſte, and affords a ſmall quantity of precipitate by alkalis.

Metallic combinations.

Biſmuth and its calx are ſoluble in this acid, though ſparingly. Nickel is diſſolved, and the ſolution affords green cryſtals. Regulus of arſenic is inſoluble, but its calx is taken up. The regulus of cobalt is likewiſe inſoluble; its calx affords a pale roſe-coloured ſolution, which is a ſympathetic ink, and receives a green colour from marine acid. Zinc is ſoluble not only in its metallic and calciform ſtates, but alſo, as it is ſaid, when mixed with other metals: hence it ſhould ſeem ill calculated to defend copper veſſels from the action of this vegetable acid. The ſolution of zinc in common acetous acid affords plated cryſtals. Regulus of antimony is very ſparingly acted on by the acetous acid; inſomuch that it might be judged that no action took place, if it did not impart an emetic quality to the fluid. Manganeſe is not acted on by this acid but with great difficulty, though repeated diſtillations at length combine the two ſubſtances. It has not been aſcertained whether the acetous acid has any action upon wolfram or molybdena.

Zinc an improper material to defend copper veſſels.

BOOK II.

PARTICULAR CHEMISTRY.

SECTION VI.

CONCERNING THE PRODUCTS OF THE ANIMAL KINGDOM.

CHAP. I.

A SHORT ENUMERATION OF SUCH ANIMAL SUBSTANCES AS HAVE BEEN EXAMINED BY CHEMISTS.

ANIMAL SUBSTANCES.

Analyſis and arrangement. Page 411—415.

THE general ſtructure and methods of analyſing animal ſubſtances have been already noticed. It therefore remains only to enumerate and deſcribe the ſeveral products of this kingdom, which have engaged the attention of chemiſts. In the arrangement of theſe, as in the vegetable kingdom, we cannot, on account of the imperfect ſtate of our knowledge, have recourſe to the nature of their component parts; but

ANIMAL SUBSTANCES.

Enumeration.

ſhall rather attend to the means by which they are reſpectively afforded or obtained. In this way we may conſider the parts of animals as either,

1. Such as are uſually obtained without deſtroying life. Theſe are milk, eggs, urine, excrement, the matter of perſpiration, ambergris, &c.; wax, honey, gum lac, ſilk, hair, horn, feathers, &c. Or,

2. Such parts of animals as are obtained by deſtroying them, or depriving them of life. Theſe are blood; various ſolids, confounded under the name of fleſh, fat, ſpermaceti; bile, the gaſtric juice, and ſeveral acids; together with calcareous earth, and other ſubſtances, common to the mineral and vegetable kingdoms.

CHAP. II.

CONCERNING MILK, EGGS, HONEY, WAX, LACCA, SILK, HAIR, HORN, ETC.

MILK.

General characters of milk.

MILK is a well-known fluid, ſecreted in peculiar veſſels of the females of the human ſpecies, of quadrupeds, and of cetaceous animals, and deſtined for the purpoſe of nouriſhing their young. Its appearance and component parts are not altogether the ſame in various ſpecies of animals; but the differences have not yet been well aſcertained. For this reaſon, in treating of milk, our attention will be confined to that of the cow, becauſe the moſt abundantly met with. This fluid is of a beautiful opake white colour, nearly as limpid as water, and of a pleaſant emulſive taſte. Its appearance on the ſtage of a microſcope exhibits an infinity of minute opake globules floating in a tranſparent fluid.

Effects of heat on cows milk.

Cows milk, diſtilled on a water bath, affords a taſteleſs phlegm of a faint ſmell, which is capable of putrefying. A ſtronger heat coagulates it. It is ſometimes gradually dried into a ſubſtance which is a kind of ſaccharine extract, and may again be diffuſed in water. By deſtructive diſtillation, milk affords an acid, a fluid oil, a concrete oil, and volatile alkali. Its reſidual coal contains a ſmall quantity of vegetable alkali, ſome ſalt of Sylvius, and phoſphoric calcareous ſalt.

When milk is left to ſpontaneous decompoſition, at a due temperature, it is found to be capable of paſſing through the vinous, acetous, and putrefactive fermentations. It appears however, probably on account of the ſmall quantity of ardent ſpirit it contains, that the vinous fermentation laſts a very ſhort time, and can ſcarcely be made to take place in every part of the fluid at once by the addition of any ferment. This ſeems to be the reaſon why the Tartars, who make a fermented wine from mares milk, called koumiſs, ſucceed by uſing large quantities at a time, and agitating it very frequently.

Fermentation of milk.

Page 465.

When milk is left expoſed for ſome hours in a ſtate of repoſe, a ſmall quantity of thick fluid riſes to the top, and is known by the name of cream. This contains the fat ſubſtance called butter, which is afterwards ſeparated from it by agitation in the act of churning. The remainder afterwards becomes ſour, and undergoes a coagulation which ſeparates it into two parts—a ſolid curd; and a fluid, called ſerum or whey. This ſour whey contains a peculiar acid, called the acid of milk, and likewiſe a portion of vinegar. The peculiar acid does not riſe in diſtillation, but may be ſeparated by evaporating the filtered whey to one eighth; and precipitating the phoſphoric ſalt by the addition of lime-water, which fully ſaturates its acid: the fluid is then to be diluted with three times its weight of water; and the redundant lime precipitated by ſaccharine acid, in which operation the exceſs of the laſt-mentioned acid may be guarded againſt by the teſt of a ſmall portion of lime-water. This purified liquor muſt then be evaporated to the conſiſtence

Cream.

Butter.

Acid of milk.

ſiſtence of honey; and the other foreign ſubſtances it may contain will be ſeparated by the addition of pure ardent ſpirit, which takes up the acid of milk only. The decanted ſolution being then diluted with water, and heated, the ardent ſpirit flies off, and leaves the acid of milk behind, diſſolved in the water.

Acid of milk.

This acid does not afford cryſtals; and, when evaporated to dryneſs, it deliqueſces again by expoſure to air. With vegetable alkali it affords a deliqueſcent ſalt, ſoluble in ardent ſpirit. With mineral alkali it affords a ſalt poſſeſſing the ſame properties. With volatile alkali it produces a deliqueſcent ſalt, which yields much of its alkali by diſtillation before the acid is deſtroyed by heat. With lime, clay, and ponderous earth, it forms deliqueſcent ſalts; but with magneſia it affords ſmall cryſtals, which at length deliqueſce. The acid of milk diſſolves iron and zinc, and produces inflammable air. Copper affords a dark blue ſolution, which does not cryſtallize. Lead is diſſolved after ſome days digeſtion, and affords veſtiges of vitriolic acid. Biſmuth, cobalt, antimony, tin, mercury, ſilver, and gold, are not affected by this acid in a digeſtive or boiling heat. Deſtructive diſtillation decompoſes the acid of milk: water firſt comes over; then a weak acid, reſembling the empyreumatic acid of tartar; afterwards ſome empyreumatic oil, with more of the ſame acid, and alſo fixed air, and the heavy inflammable air. A coal remains in the retort.

Combinations with various ſubſtances.

If any vegetable or mineral acid be added to milk, the curd is ſeparated, and coagulates into one maſs, if the

Curd.

the mixture be aſſiſted by the application of heat. The curd obtained by means of mineral acid, always manifeſts ſigns of acidity, and is partially ſoluble in boiling water. If any neutral, earthy, or metallic ſalt be added to ſaturation in milk, it likewiſe ſeparates the curd. Sugar and gum-arabic produce a ſimilar effect. Cauſtic alkalis diſſolve the curd, by the aſſiſtance of a boiling heat; and it may again be coagulated by the addition of acids.

Manufacture of cheeſe:

The coagulation of milk, in the manufacture of cheeſe, is effected by the addition of rennet, which is the infuſion of the ſtomach of a ſucking calf in water, prepared in various ways, according to the fancy of the makers. This fluid ſeems to owe its properties to the gaſtric juice of the animal. The ſeparated curd is wrapped in a cloth with ſalt, and preſſed, to deprive it of the ſuperfluous whey; after which, it is preſerved for ſeveral months or years before it is conſidered as fit for uſe.

— properties.

Cheeſe, when decompoſed by deſtructive diſtillation, affords an alkaline phlegm, an heavy oil, and much volatile alkali. Its reſidual coal is difficult to incinerate, and does not afford fixed alkali. By treating it with the nitrous acid, it is found to contain lime and phoſphoric acid. Cheeſe is not ſoluble in water. Hot water hardens it.

Sugar of milk.

The ſaccharine ſubſtance, upon which the fermenting property of milk depends, is held in ſolution by the whey which remains after the ſeparation of the curd in making cheeſe. This is ſeparated by evaporation in the large way, for pharmaceutical purpoſes, in various parts of Switzerland. When the whey has been

Sugar of milk:

been evaporated by heat, to the conſiſtence of honey, it is poured into proper moulds, and expoſed to dry in the ſun. If this crude ſugar of milk be diſſolved in water, clarified with whites of eggs, and evaporated to the conſiſtence of ſyrup, white cryſtals, in the form of rhomboidal parallelopipedons, are obtained.

— Decompoſition by heat:

Sugar of milk has a faint ſaccharine taſte, and is ſoluble in three or four parts of water. It yields by diſtillation the very ſame products that other ſugars do. It is remarkable, however, that the empyreumatic oil has a ſmell reſembling flowers of benzoin. Twelve ounces of diluted nitrous acid being poured upon four ounces of finely powdered ſugar of milk, in a glaſs retort, on a ſand-bath, with a receiver annexed, the mixture became gradually hot, and at length effervefced violently, and continued to do ſo for a conſiderable time after the retort was taken from the fire. It is neceſſary therefore, in making the experiment, to uſe a large retort, and not to lute the receiver too tight to the retort. After the effervefcence had in ſome meaſure ſubſided, the retort was again placed on the ſand-bath, and the nitrous acid diſtilled off, till the maſs acquired a yellowiſh colour. This yellow fluid exhibited no cryſtals. Eight ounces more of the ſame nitrous acid were therefore added, and the diſtillation again repeated, till the yellow colour of the fluid diſappeared. The fluid became inſpiſſated by cooling; it was therefore rediſſolved in eight ounces of water, and filtered. Seven drams and a half of a white powder remained on the filter, and the clear ſolution afforded cryſtals of ſaccharine acid. The mother water was again treated ſeveral times with nitrous acid, by which

— treatment with nitrous acid.

which means the whole was at length changed into ſaccharine acid.

Peculiar acid of ſugar of milk.

The white powder that remained on the filter was found to be combuſtible like oil in a red hot crucible, without leaving any mark of aſhes behind. It was ſoluble in ſixty times its weight of boiling water; and one fourth part ſeparated by cooling, in the form of very ſmall cryſtals. The remaining maſs being then collected, by evaporating the greateſt part of the water, left behind a ſmall portion of the acid of ſugar, of which it had not been ſo exactly deprived by edulcoration on the filter. From theſe circumſtances it appeared that the white matter was a ſalt; and, upon examination, it was found to be an acid, poſſeſſing the following properties:

Combinations.

With all the ſoluble earths it forms ſalts inſoluble in water. It diſengages fixed air from the mild alkalis. With vegetable alkali it forms a cryſtallizable ſalt, ſoluble in eight times its quantity of boiling water, and ſeparable for the moſt part by cooling. With the mineral alkali it forms a ſalt which requires only five parts of boiling water for its ſolution. Both theſe ſalts are perfectly neutral. When ſaturated with volatile alkali, it forms a ſalt which, after being gently dried, has a ſouriſh taſte. It does not perceptibly act on the metals; but forms with their calces, in ſolution, ſalts of very difficult ſolubility, which are therefore precipitated *.

The principles of milk appear to be united together partly in a chemical, and partly in a mechanical

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* On milk and its acid, and on the acid of the ſugar of milk, conſult the Chemical Eſſays of Scheele.

manner; and the butter ſeems to riſe to the top in conſequence of the greater ſpecific gravity of the whey through which it is diſperſed. Cream conſiſts of butter mixed with much whey and curd. It is generally thought that the ſeparation of the butter by churning is effected ſimply by the agitation, which cauſes the fatty particles to ſtrike againſt each other, and coagulate into larger maſſes. There ſeems however ſome reaſon to think that a chemical effect takes place in this operation; in which the intimate mixture of atmoſpheric air with the fluid may perhaps have ſome effect.

Separation of butter from cream:

Butter appears to be of the nature of fat oils; but is conſidered by moſt nations as infinitely preferable to them, as an article of food. By diſtillation on a water-bath it gives out the aqueous fluid which, from the manner of its fabrication, is diſtributed through its maſs. Its products, by deſtructive diſtillation, nearly reſemble thoſe of other oils. They conſiſt of an acid of a ſtrong and penetrating ſmell, a fluid oil, and a concrete oil of the ſame ſmell as the acid. Theſe oils, like others obtained in ſimilar circumſtances, may, by repeated rectifications, be converted into volatile oils, of the nature of thoſe which are called eſſential. In other reſpects, butter poſſeſſes the ſame properties, and may be applied to the ſame uſes as fat oils. It becomes rancid by ſpontaneous decompoſition, which developes its acid; and with fixed alkalis it forms ſoap.

—its properties.

The eggs of birds conſiderably reſemble milk in their component parts, though their peculiar ſtructure

Eggs.

and organization conſtitute a great and eſſential difference, applicable to the purpoſes of generation, into which our preſent views do not require us to proceed. The white of egg does not greatly differ from the curd of milk or cheeſe. When it is mixed with water, it forms a coagulum or curd by the addition of acids. Heat coagulates the white of egg, without depriving it of weight; which is a very ſingular fact, and has not yet been well explained. The white of egg however appears to differ, in ſome reſpects, from curd. It is ſaid to afford a ſmall portion of ſulphur by ſublimation; and it contains the mineral alkali in a diſengaged ſtate.

Reſemblance between white of egg and curd of milk.

Yolk of egg.

The yolk of egg appears to be an animal emulſion, which is diffuſible in water. It contains an oil, which may be ſeparated by drying, and afterwards ſubjecting it to preſſure.

Honey and wax.

Honey and wax may be conſidered as animal ſubſtances, becauſe afforded by the bee; though it is not improbable but theſe laborious inſects may extract them from the veſſels of plants, and depoſit them in their hives without alteration.

Purification of honey.

Honey which is purified by ſolution and cryſtallization, perfectly reſembles the ſaccharine juices of vegetables which have undergone the like treatment. It affords the ſame product as ſugar by deſtructive diſtillation. Nitrous acid converts it into the ſaccharine acid, and its aqueous ſolution is ſuſceptible of all the ſtages of fermentation. It is accordingly, as we have before obſerved, made uſe of in the preparation of a vinous liquor.

Page 465.

WAX.

Diſtillation of wax.

Wax is a concrete ſubſtance, which greatly reſembles the more ſolid fixed oils, and unites with oily ſubſtances in all proportions. Its products, by deſtructive diſtillation, are the ſame as thoſe of other fat ſubſtances. The concreſcible oil obtained by diſtillation of this ſubſtance, is called butter of wax. Bees-wax is of a yellow colour, but becomes white by expoſure to air: this effect takes place only at or near the ſurface or place of contact; for which reaſon the bleachers of wax find it neceſſary to renew the ſurface frequently. This is done either by cauſing the melted wax to paſs through a number of holes in the bottom of a veſſel into another veſſel of water, by which means it undergoes that kind of diviſion which, in metallic bodies, is called granulation; or it is gently poured upon a wooden cylinder, which is turned round in a veſſel filled with water to ſuch a height, that half of the cylinder is immerſed. In this way, the wax forms a number of thin flakes, that do not adhere to each other, but may be taken off, and expoſed to the action of the air. The dephlogiſticated or aërated marine acid bleaches wax very ſpeedily; from which fact it appears that the wax owes its whiteneſs, and the greater conſiſtency it acquires, to an abſorption of the vital part of the atmoſphere. Wax ſeems to differ from tallow, or concrete oil, principally in this circumſtance: and this laſt ſubſtance becomes likewiſe harder and whiter by long expoſure to the air, in thin maſſes; as, for example, when it is ſpread out upon the ſurface of water. Wax being already combined with a portion of vital air, does not burn with ſo luminous a flame as tallow or oil. But it poſſeſſes a very great

Butter of wax.

Bleaching.

Difference between wax and tallow.

great advantage in the fabrication of candles, which ariſes from the circumſtance of its freezing point being placed at a conſiderably higher temperature than thoſe of either of the other two ſubſtances.

An explanation of the chief advantage of wax candles compared with thoſe of tallow.

To explain this advantage, it muſt be conſidered, that oils do not take fire, unleſs they be previouſly volatilized by heat. The wick of a candle, or lamp, anſwers this purpoſe. The oil riſes between the fibres of the wick by the capillary attraction. Heat is applied to the extremity of the wick, which volatilizes and ſets fire to a portion of the oil. While this is diſſipated by combuſtion, another portion paſſes along the fibres, and ſupplies its place by becoming heated and burned likewiſe. In this way a conſtant combuſtion is maintained. It muſt be remarked, however, that a candle differs from a lamp in one very eſſential circumſtance, namely, that the oil, or tallow, is liquefied only as it comes to be in the vicinity of the conflagration; and this fluid is retained in the hollow of the part which is ſtill concrete, and forms a kind of cup. For this reaſon, it is found neceſſary that the wick ſhould not be too thin; becauſe, in this caſe, it would not carry off the fluid as faſt as it becomes fuſed; and the conſequence would be, that it would run down the ſides of the candle: and, as the inconvenience ariſes from the fuſibility of the oil, it is plain that a more fuſible candle will require a larger wick; or that the wick of a wax candle may be made thinner than that of one of tallow.

The difference of effect, in illumination, between a thick and a thin wick, cannot be better ſhewn than by remarking the appearances produced by both. When

The uſe and effects of the wick in candles.

a candle with a thick wick is firſt lighted, and the wick ſnuffed ſhort, the flame is perfect and luminous, unleſs its diameter be very great; in which laſt caſe, there is an opake part in the middle, where the combuſtion is impeded for want of air. As the wick becomes longer, the ſpace between its upper extremity and the apex of the flame is diminiſhed; and conſequently the oil which iſſues from that extremity, having a leſs ſpace of ignition to paſs through, is leſs completely burned, and paſſes off partly in ſmoke. This evil continues to increaſe, until at length the upper extremity of the wick projects beyond the flame, and forms a ſupport for an accumulation of ſoot, which is afforded by the imperfect combuſtion. A candle, in this ſituation, affords ſcarcely one tenth of the light which the due combuſtion of its materials would produce; and tallow-candles, on this account, require continual ſnuffing.—But, on the contrary, if we conſider the wax candle, we find that, as its wick lengthens, the light indeed becomes leſs, and the cup becomes filled with melted wax. The wick however, being thin and flexible, does not long occupy its place in the center of the flame; neither does it, when there, enlarge the diameter of the flame ſo as to prevent the acceſs of air to its internal part. When its length is too great for the vertical poſition, it bends on one ſide; and its extremity, coming into contact with the air, is burned to aſhes; excepting ſuch a portion as is defended by the continual afflux of melted wax, which is volatilized, and completely burned, by the ſurrounding flame. We ſee therefore that the difficult fuſibility of wax renders it practicable to burn a large quantity of

WAX. LACCA. fluid by means of a ſmall wick; and that this ſmall wick, by turning on one ſide in conſequence of its flexibility, performs the operation of ſnuffing upon itſelf, in a much more accurate manner than it can ever be performed mechanically.

Wax is not ſoluble in ardent ſpirit.

Stick-lac, ſhell-lac, and ſeed-lac: Lac, or lacca, is a ſubſtance well known in Europe, under the different appellations of ſtick-lac, ſhell-lac, and ſeed-lac. The firſt is the lac itſelf, which is a brown ſemi-tranſparent ſubſtance, in pretty conſiderable lumps, with woody parts adhering to it. Seed-lac is the ſtick-lac broken in pieces, and appearing in a granulated form. Shell-lac is the ſubſtance which has undergone a ſimple purification.

—its production. Lac is the product of an inſect *, which depoſits its eggs on the branches of a tree called Bihar, in Aſſam, a country bordering on Thibet, and elſewhere in India. It appears deſigned to anſwer the purpoſe of defending the eggs from injury, and affording food for the maggot in a more advanced ſtate. It is formed into cells, finiſhed with as much art and regularity as an honey-comb, but differently arranged; and the inhabitants collect it twice a year, in the months of February and Auguſt. For the purification, it is broken into ſmall pieces, and put into a canvas bag of about four feet long, and not above ſix inches in circumference. Two of theſe bags are in conſtant uſe, and each of them held by two men. The bag is placed over a fire, and frequently turned, till the lac is liquid enough to paſs

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* For a deſcription, conſult Kerr, in the Phil. Tranſ. vol. lxxi. p. 374.

through its pores; when it is taken off the fire, and twiſted in different directions by the men who hold it, at the ſame time dragging it along the convex part of a plantain tree prepared for that purpoſe; and, while this is doing, the other bag is heating, to be treated in the ſame way. The mucilaginous and ſmooth ſurface of the plantain tree prevents its adhering; and the degree of preſſure regulates the thickneſs of the coating of lac, at the ſame time that the fineneſs of the bag determines its clearneſs and tranſparency *.

Purification of lac.

Characters.

Lac is not entitled to arrangement either with oils, reſins, or gums. It is not ſoluble either in water, or in fat oils. Some eſſential oils appear to extract a dilute tincture. The action of the acids upon lac, either when concentrated or diluted, does not ſeem to be conſiderable; but this requires more particular examination, eſpecially as far as relates to the nitrous acid. Ardent ſpirit acts but feebly on this ſubſtance. By ſtanding upon it in the cold, it forms a clear tincture, apparently by diſſolving only a part of its principles; but, when digeſted in a moderate heat, the whole of the lac unites with the ſpirit, and forms a turbid mixture, or imperfect ſolution, of a gummy appearance, which does not afterwards become clear. In this way, however, with judicious management, it appears practicable to form a very hard opake varniſh, reſembling that of China or Japan. The principal uſe of lac is in the manufacturing of ſealing-wax, and in dying ſcarlet. For this laſt purpoſe, half a dram of powdered comfrey root is to be boiled in a quart of

Hard varniſh.

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* Saunders, in Phil. Tranſ. vol. lxxix.

LACCA. SILK.

Uſes of lac.

water for a quarter of an hour, and ſome powdered gum lac digeſted in the decoction for two hours. The tincture appears of a fine crimſon colour; and the remaining lac, if the quantity of liquor has been ſufficient, is of a pale ſtraw colour. The clear tincture being then poured off, and a ſolution of alum gradually added, the colouring matter ſubſides, in the form of one of the powders called lakes, which amounts to about one fifth part of the weight of the lac. This fecula is diſſolved in warm water, with the addition of a proper quantity of the ſolution of tin in aqua regia: and the liquor, which is of a fiery red colour, is then to be poured into boiling water, impregnated with ſalt of tartar, or the mild fixed vegetable alkali. The bath, thus formed, is a good ſcarlet dye for woollens, though leſs lively than that of cochineal.

Lewis on Neumann.

Silk, and the acid of ſilk-worms.

Silk is a well-known ſubſtance, which ſerves as a nidus for the chryſalis of the ſilk-worm. Its extenſive utility, when contraſted with the ſmall proſpect of advantage which its appearance in the crude ſtate ſeems to afford, may ſerve to ſtimulate our induſtry in the examination of other natural products; many of which, though neglected at preſent, might, on enquiry, be found equally beneficial to ſociety. This ſubſtance ſeems to hold a middle rank between animal and vegetable matters. It affords volatile alkali by diſtillation, and gives out phlogiſticated air when treated with nitrous acid. By diſtilling the nitrous acid from this ſubſtance, the acid of ſugar is obtained, and likewiſe a peculiar oil. The phalæna, or moth of the ſilk-worm, ejects a liquor which appears to contain a peculiar acid, hitherto little examined. It is obtained in a ſtate of purity by infuſing the chryſalides in ardent ſpirits, and ſubſequent evaporation.

SILK. WOOL.

Animal excreſcences.

The hair and wool of animals do not ſeem to differ greatly from ſilk. They afford much acid of ſugar, when treated with nitrous acid. It is probable that horns, feathers, and other ſimilar excreſcences of animals, are nearly of the ſame nature.

CHAP. III.

CONCERNING THE EXCREMENTITIOUS PARTS OF ANIMALS.

EXCREMENTITIOUS MATTERS.

Urine and fecal matter.

THE ſubſtances which are rejected out of the bodies of animals, as uſeleſs, are urine, and the fecal matter, or excrement. Theſe differ in the various ſpecies of animals, according to their reſpective natures and food. But little attention has been paid by chemiſts to the urine or excrements of any animals except the human ſpecies. We have already had occaſion to mention the contents of urine, in treating of the phoſphoric acid, in our account of the mineral kingdom; and ſhall therefore, in the preſent place, confine our remarks to that peculiar depoſition which is known by the name of the urinary calculus, or ſtone of the bladder.

Page 208.

Stone of the bladder.

The matter which forms theſe hard concretions is found in all urine; and is depoſited by cooling, after the greateſt part is evaporated. Heat again diſſolves it. In about three hundred times its weight of boiling water it is either totally ſoluble, or it leaves a very inconſiderable reſidue, which ſeems to be an impurity. As the fluid becomes cold, moſt of the calculus is again ſeparated in fine cryſtals. The vitriolic acid diſſolves it with efferveſcence; the marine acid does not appear to act upon it; and the nitrous acid totally diſſolves it. This ſolution affords no precipitate by the acid of ſugar, though the vitriolic acid throws down a ſmall portion of ſelenite: whence it appears that the calculus contains ſome lime. Pure alkalis diſſolve it, as does likewiſe lime-water. By deſtructive diſtillation, the calculus affords fluid volatile alkali, and a ſublimate of a brown colour, which by a ſecond ſublimation becomes white. This has a ſouriſh taſte, is eaſily ſoluble in boiling water, and alſo in ardent ſpirit.

Acid of the ſtone of the bladder.

From the above, and other experiments, it appears that the calculus conſiſts of an acid of a volatile nature, together with ſome gelatinous or oily matter, and a ſmall portion of lime. The acid itſelf may probably be a compound ſalt with exceſs of acid, ſimilar to the combinations of mineral alkali and phoſphoric acid, vegetable alkali and tartareous acid, and ſome others which were conſidered as ſimple acids, until chemiſts had deviſed means of ſeparating their component parts. We ſee therefore that the analyſis of the ſtone of the bladder has not yet been perfectly made.

Page 209.

Homberg's experiments on human excrement.

However important the knowledge of the component parts of fecal matter may be, to facilitate our acquaintance with the animal ſyſtem, it may eaſily be imagined that the purſuits of the majority of chemiſts would be directed to departments of the ſcience; which promiſed effects of a leſs diſguſting nature. We poſſeſs but one ſet of experiments made on this ſubſtance, by Homberg, at the beginning of the preſent century. This philoſopher, in conſequence of alchemiſtical information, inſtituted a ſet of operations upon the fecal matter of men fed entirely upon bread of Goneſſe *, and Champagne wine. He found that,

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* A ſmall town near Paris, where the moſt excellent bread is made.

when

Homberg's experiments on the human fecal matter.

when recent, it afforded, by diſtillation to dryneſs, an aqueous, clear, inſipid liquor, of a diſagreeable odour, which contained no volatile alkali; but, by continuing to diſtil the reſidue by a graduated fire, he obtained fluid and concrete volatile alkali, a fetid oil, and a coaly reſidue; ſubſtances which this imperfect method of analyſis exhibits with every kind of animal ſubſtance.

The human fecal matter, by lixiviation in water, filtration, and ſubſequent evaporation, afforded an oily ſalt reſembling nitre, which was fuſed on ignited coals, and took fire when heated to a certain degree in cloſed veſſels. The ſame fecal matter, after it had undergone a complete putrefaction for forty days, in the gentle heat of a water-bath, afterwards afforded by diſtillation a colourleſs oil without ſmell, which was the thing ſought after; but it did not fix mercury, as he had been led to expect.

Imperfect as this examination is, it is rendered ſtill leſs generally applicable by the peculiar nature of the aliments from which the matter originated. For it cannot be doubted but that, as the excrements are the reſidue of the food taken, they will differ according to the nature of that food; as is indeed ſufficiently evinced from their more obvious qualities.

Ambergris.

It is at preſent a general opinion *, that ambergris is an excrementitious ſubſtance, voided by the phyſeter

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* Chiefly grounded on the enquiries and obſervations of Dr. Swediar, in the Phil. Tranſ. for 1783. Mr. Magellan however mentions an undoubtedly vegetable ambergris, gathered from the tree by M. Aublet, and examined by Rouelle. Cronſtedt's Mineralogy, p. 458.

ſeter macrocephalus, or ſpermaceti whale. Ambergris is found in the ſea, near the coaſts of various tropical countries; and is either white, black, aſh-coloured, yellow, or grey, with black or yellow ſpecks. A ſlight warmth ſoftens it, like pitch; by a greater heat it takes fire; and its chemical products reſemble thoſe of bitumens, among which it has uſually been ranked. Oils diſſolve it; as does likewiſe ardent ſpirit, if its quantity be twelve times that of the ambergris, and its temperature boiling. An addition of eſſential oil promotes the ſolution.

Characters of ambergris.

Various other matters are rejected from animals; ſuch as the matter of perſpiration, the naſal mucus, tears, &c. But as none of theſe have been examined, we ſhall avoid entering into any detail of their obvious properties.

Matter of perſpiration, &c.

CHAP.

CHAP. IV.

CONCERNING THE BLOOD, AND THE OTHER FLUID OR SOLID MATTERS, OF WHICH ANIMALS ARE FORMED.

PARTS OF ANIMALS.

The blood:

— differences.

THE fluid which firſt preſents itſelf to obſervation when the parts of living animals are divided or deſtroyed, is the blood, which circulates with conſiderable velocity through veſſels called veins and arteries, diſtributed into every part of the ſyſtem. It can ſcarcely admit of doubt but that the component parts, or immediate principles of the blood, muſt differ in the various and exceedingly diſſimilar genera and ſpecies of animals which occupy the land and waters of the globe; and that there are likewiſe differences in the ſtate or compoſition of this fluid in the ſame animal, according to its ſtate of health, as well as the ſituation of the veſſels from which it may be extracted. Theſe differences can be aſcertained only by the united efforts of the anatomiſt and the chemiſt. But as the difficulty and extent of the ſubject have hitherto prevented any conſiderable progreſs, it becomes an object of neceſſity to confine our attention to the blood of man, or of ſuch quadrupeds as afford this fluid in a ſtate not obviouſly different from that of the human ſpecies.

Recent blood is uniformly fluid, and of a ſaline or ſlightly ferruginous taſte. Under the microſcope it appears

Characters of the blood.

appears to be compoſed of a prodigious number of red globules ſwimming in a tranſparent fluid. After ſtanding for a ſhort time, its parts ſeparate into a thick red matter, or craſſamentum, and a fluid called ſerum. If it be agitated till cold, it continues fluid; but a conſiſtent polypous matter adheres to the ſtirrer, which by repeated ablutions with water becomes white, and has a fibrous appearance: the craſſamentum becomes white and fibrous by the ſame treatment. If blood be received from the vein in warm water, a ſimilar filamentous matter ſubſides, while the other parts are diſſolved. Alkalis prevent the blood from coagulating; acids, on the contrary, accelerate that effect. In the latter caſe the fluid is found to contain neutral ſalts, conſiſting of the acid itſelf united with mineral alkali, which conſequently muſt exiſt in the blood, probably in a diſengaged ſtate. Ardent ſpirit coagulates blood. On the water-bath, blood affords an aqueous fluid, neither acid nor alkaline; but of a faint ſmell, and eaſily becoming putrid. A ſtronger heat gradually dries it, and at the ſame time reduces it to a maſs of about one eighth of its original weight. In this ſtate it ſlightly attracts the humidity of the air, and efferveſces with acids; but by a longer expoſure, for ſome months, it becomes covered with an effloreſcence of mild mineral alkali. By deſtructive diſtillation this animal fluid affords a watery liquor, holding in ſolution a neutral ſalt, with exceſs of volatile alkali, but whoſe acid part has not been well aſcertained: next follows a light oil, a denſe coloured oil, and foul or oleaginous volatile alkali. The reſidue is a coal of very difficult incineration, containing common ſalt, mineral

Habitudes with acids, &c.

Diſtillation.

mineral alkali, and an earth, which is probably a combination of lime and phoſphoric acid.

Serum of blood: The ſerum of blood exhibits marks of a diſengaged alkaline ſalt, and is greatly diſpoſed to putrefy. It unites with water in all proportions, and forms a milky fluid, which may be coagulated by acids or ardent ſpirit. An increaſe of temperature cauſes ſerum to become conſiſtent, with little or no loſs of weight, in the ſame manner as the white of egg; and it is accordingly uſed for the ſame purpoſe in clarifying liquids.

— reſembles white of egg, curd, and vegetable gluten: From a variety of experiments, it appears highly probable that white of egg, ſerum of blood, and the pure curd of milk, do not eſſentially differ from each other: and to theſe we may perhaps add the vegetable gluten, which conſiderably reſembles cheeſe.

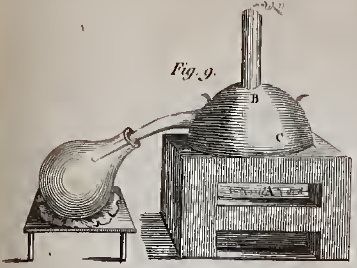
— with alkalis and acids: Alkalis render the ſerum of blood more fluid; acids coagulate it, and exhibit the neutral ſalt they would have produced by direct combination with mineral alkali. The coagulum affords, by diſtillation, phlegm, mild volatile alkali, and a thick fetid oil; and the reſidue affords mild mineral alkali. Theſe products are the ſame as are afforded by the ſerum itſelf.

— with ardent ſpirit: Serum is alſo coagulated by ardent ſpirit, merely by the loſs of part of its water.

— nitrous acid. When rendered concrete by heat, and expoſed to the action of nitrous acid, it affords phlogiſticated air by a ſlight heat, which is followed by nitrous air; and the reſidue affords acid of ſugar, together with a ſmall portion of acid of apples.

Craſſamentum. The craſſamentum of blood, when treated in the way of diſtillation, becomes dry and brittle, at the ſame time that it emits an alkaline phlegm; this is followed by an empyreumatic ſtinking oil, and concrete volatile alkali.

To face page 512.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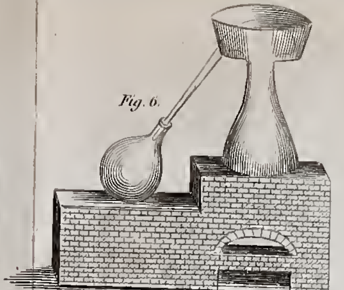
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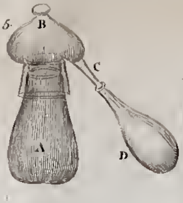
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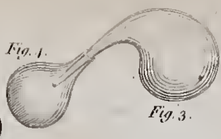
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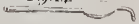
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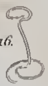
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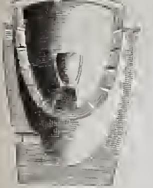
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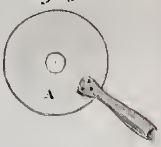
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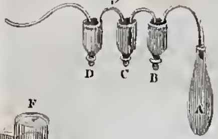
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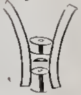
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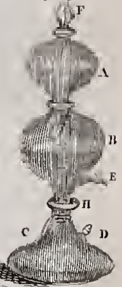
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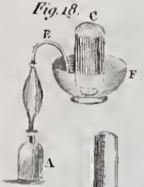
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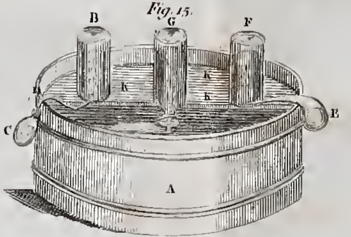
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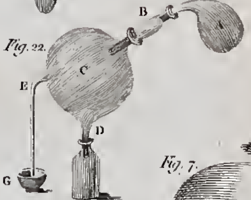
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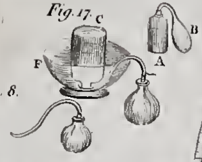
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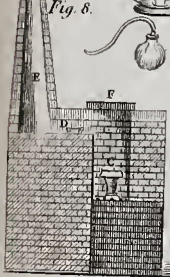
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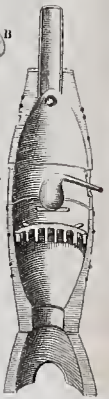
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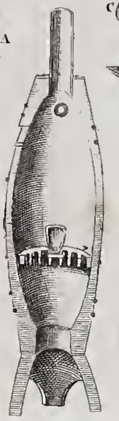
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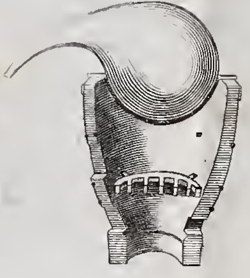
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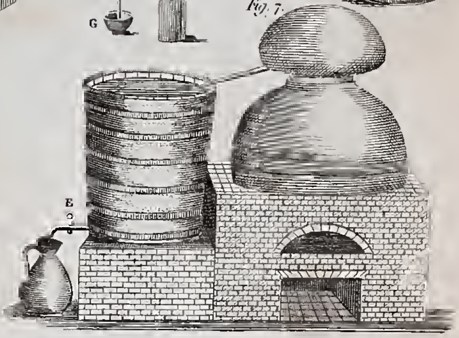
Fig. 7.

alkali. A ſpungy brilliant coal remains, which by treatment with vitriolic acid is found to contain mineral alkali and iron, as appears by the production of Glauber's ſalt and martial vitriol: coaly matter and phoſphorated lime are then left behind.

PARTS OF ANIMALS.

Fibrous part of blood:

The fibrous matter, which is obtained by waſhing the red part of the blood, reſembles the ſerum in many of its properties; though it differs from it in not being ſoluble in water, in becoming hard by a very gentle heat, and in not combining with alkalis. Acids unite with it, and in particular the nitrous acid diſſolves it, and extricates phlogiſticated and nitrous air; while the reſidue, by evaporation, affords acid of ſugar in cryſtals, a peculiar oil in flocks, and the phoſphoric ſalt of lime. Its volatile products by deſtructive diſtillation are nearly the ſame as thoſe of ſerum: but its reſidue contains no ſalt, except the combination of lime and phoſphoric acid; the other ſalts it might have contained having probably been carried off during the waſhing. Marine acid forms a green jelly with the fibrous parts of the blood.

— with acids.

Deſtructive diſtillation.

Soft parts of animals.

Jelly or glue.

The ſoft and flexible parts of animals appear to be compoſed of principles greatly reſembling thoſe of the blood. When they are boiled in water, the fluid extracts that peculiar animal ſubſtance which is known by the name of jelly or glue. This is afforded by the white parts moſt plentifully, though it is found in almoſt every part of the animal ſolids. Its appearance and inſipidity, together with its other obvious properties, are well known. It is ſoluble in water, in all proportions; is more fluid when hot than when

Jelly or glue.

cold. Alkalis and acids both diſſolve it. By ſpontaneous decompoſition it firſt becomes acid, and ſoon afterwards putrefies. By deſtructive diſtillation it affords an alkaline phlegm, an empyreumatic oil, and a ſmall quantity of volatile alkali. The reſidual coal is voluminous, not eaſily incinerated, and contains common ſalt, with the phoſphoric ſalt of lime. The habitude of the nitrous acid with glue, or jelly, is the ſame as with other animal ſubſtances; phlogiſticated air and nitrous air are diſengaged, and the reſidue affords acid of ſugar.

Analyſis of the fleſh of animals.

Beſides the parenchymatous and cellular ſubſtance of which the muſcles of animals are formed, their veſſels contain fluids poſſeſſed of various properties. Theſe may be obtained by preſſure, and the judicious application of water and ardent ſpirit, either with or without heat. If fleſh be waſhed in cold water, a portion of blood and gelatinous matter, together with ſaline matter, are extracted: the reſidue being digeſted in ardent ſpirit, is by that means deprived of an extractive or ſaponaceous ſubſtance; and ſubſequent ebullition in water diſſolves the gelatinous part, at the ſame time that it deprives it of ſuch portions of extract and ſalt as had been defended from the action of the two former ſolvents. The fat is alſo liquefied by this operation, and ariſes to the ſurface. By ſlow evaporation of the aqueous ſolution, made in the cold, the albuminous part, or ſerum, coagulates, and may be ſeparated on the filter: the filtered liquor will afford its ſalt by evaporation: the ſpirituous ſolution depoſits the extractive matter by evaporation: and the decoction affords the jelly, with the fat oil, which ſwims at the ſurface and congeals by cooling. The remaining ſolid ſubſtance conſiſts merely of the fibrous matter, which is white, inſipid, and inſoluble in water. This affords much volatile alkali, and a very fetid oil, by diſtillation; and it gives out a large quantity of phlogiſticated air when treated with nitrous acid. In a word, it has all the characters of the fibrous part of the blood, and is probably formed by the depoſition of that ſubſtance *.

Analyſis of the fleſh of animals.

The extractive or ſaponaceous matter obtained by the evaporation of the ſpirit, is ſoluble likewiſe in water; it ſwells up and liquefies by heat, and emits a ſmell ſomewhat reſembling that of burned ſugar: it is this ſubſtance which predominates in the brown cruſt that covers the ſurface of roaſted meat. The ſalt afforded by the decoction of fleſh has not been perfectly examined; but it ſeems to conſiſt of the phoſphoric acid, united partly with the vegetable alkali, and partly with lime.

Fat of animals.

The fat of animals is a ſubſtance of the ſame nature as thoſe oils, which are called fat oils in the vegetable kingdom. Its conſiſtence is various in different animals, and in different parts of the ſame animal. The fat of the human ſpecies and of quadrupeds is conſiſtent, and of a white or yellowiſh colour; the fat of the internal parts being uſually firmer than that which is placed among the muſcles. It poſſeſſes all the characters of vegetable fat oils; though the crude fat of animals appears to contain a conſiderable quantity of

Page 421.

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* Fourcroy, iv. 427.

mucilage or jelly peculiar to that kingdom, which may for the moſt part be waſhed off by agitation in a large quantity of hot water.

Acid of fat.

The acid of fat is conſidered as belonging to the animal kingdom, though indeed it is no leſs abundant in the fat oils of vegetables. It may be obtained by diſtillation. Or otherwiſe a quantity of ſuet may be melted, and mixed with quick-lime: as ſoon as the mixture is cold, it muſt be boiled in a large quantity of water. After filtration and evaporation, the calcareous ſalt formed by the combination of that earth with the acid of the fat, is obtained of a brown colour. A ſlight calcination in a crucible renders it purer, by the deſtruction of a portion of inflammable matter; and by ſolution, filtration, and the addition of a certain quantity of fixed air to precipitate the ſuperfluous lime, a clear ſolution of the acid of fat, neutralized with calcareous earth, is obtained. Evaporation of this fluid affords the pure white ſalt; and this, when diſtilled with the addition of vitriolic acid, affords the acid of fat, which comes over into the receiver, while the lime and vitriolic acid remain in the retort, in the form of ſelenite.

Characters of the acid of fat.

The general characters of the acid of fat are the following:—It is liquid, fuming, and of a penetrating ſmell; decompoſable by fire, which turns it yellow, and extricates or produces fixed air. Blue colours are ſtrongly reddened by it. Water diſſolves it in all proportions. With lime, and alſo with the fixed alkalis, it forms cryſtallizable ſalts, which are not decompoſed by heat. Siliceous earth appears to be ſoluble in, or corroded by, this acid; and it acts on ſeveral of the metals.

Method of obtaining ſpermaceti.

Spermaceti is a peculiar ſubſtance, of the nature of fat oil, which is found in the head of a ſpecies of whale. One of theſe fiſhes affords ſome tons of brains, which are firſt groſsly freed from the oil, by draining and preſſing; and afterwards more perfectly purified, by ſteeping them in a lye of alkaline ſalt and quicklime, which converts the remains of the oily matter into ſoap. The brains being then waſhed with water, appear of a ſilver whiteneſs; and nothing more is then required to complete the preparation, than to cut them in pieces with wooden knives, and ſpread them abroad to dry. Good ſpermaceti is in fine white flakes, gloſſy, and ſemi-tranſparent; rather unctuous to the touch, though dry, and in ſome meaſure friable. Its ſmell is faintiſh, though not diſagreeable; and it has ſcarcely any taſte, on account of its being either nearly or totally inſoluble in the ſaliva; expoſure to the air renders it yellowiſh and rancid in proceſs of time; and that the more readily, in proportion as the original purification has been leſs complete. It may however be rendered white and ſweet again, by ſteeping it afreſh in cauſtic alkali, and waſhing it in water.

Its character:

—and habitudes.

It is ſcarcely, if at all, more combuſtible than tallow; and is a much better material for candles, becauſe leſs fuſible and greaſy By diſtillation it totally riſes, leaving no coal behind; but its component parts do not riſe together. Four ounces of this ſubſtance afforded three ounces and a half of a clear yellowiſh butyraceous oil, reſembling oil of wax in ſmell, and coagulate in the cold, like that ſubſtance; a drachm and a half of the product conſiſted of phlegm, and the reſt was waſted or diſſipated in the proceſs *.

Habitudes of ſpermaceti with various ſubſtances.

Water has no other effect upon ſpermaceti, when boiled with it, than to ſeparate a ſmall quantity of mucilaginous, or perhaps ſaponaceous matter, which is probably an impurity. Oils diſſolve it, by the aſſiſtance of heat; hot ardent ſpirit likewiſe diſſolves it, but lets the greateſt part fall upon cooling; ether diſſolves it very readily; ſulphur combines with this ſubſtance, in the ſame manner as it does with fat oils; the nitrous and marine acids have no action on it; concentrated vitriolic acid diſſolves it, but lets it fall again by heat.

Conjecture reſpecting its ſingular properties. Page 421—423. 499.

It has been conjectured that this ſingular ſubſtance bears the ſame relation to fat oils as camphor does to the eſſential oils. Wax appears to have the ſame relation to fixed oils, as reſin has to the eſſential; that is to ſay, both have been rendered concrete by the abſorption of vital air. But ſpermaceti and camphor ſeem to differ in ſome other leading particular; probably in the abſence of acid, or of any baſis which can eaſily be acidified by the action of nitrous or other acids. Much information would no doubt be derived from a careful examination of the products which theſe ſeveral ſubſtances afford by combuſtion.

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* Neumann's Chemiſtry, by Lewis, ii. 422. Fourcroy, iv. 447, ſays that ſpermaceti forms a ſoap with cauſtic alkali; which is contrary to the poſitive aſſertion of Neumann, from whom the foregoing part of the text is taken.

The

Bones.

The bones of men and quadrupeds owe their great firmneſs and ſolidity to a conſiderable portion of the phoſphoric ſalt of lime which they contain. When theſe are raſped ſmall, and boiled in water, they afford gelatinous matter, and a portion of fat or oil, which occupied their interſtices. By deſtructive diſtillation they afford alkaline phlegm, a fetid oil, and much volatile alkali; leaving a coal not eaſily burned. In an open fire, bones are inflamed by virtue of their oil, and emit an offenſive empyreumatic ſmell. The white, friable, and incombuſtible reſidue, conſiſts chiefly of lime and phoſphoric acid in combination. It affords a ſmall quantity of mild mineral alkali by waſhing with water. This white matter is decompoſable by fuſion, with mild fixed alkalis, which unite with the phoſphoric acid, at the ſame time that the fixed air converts the lime into chalk. Acids likewiſe diſengage the phoſphoric acid, by uniting with the lime. The nitrous or the vitriolic acids are moſt commonly uſed in this proceſs.

White reſidue.

Page 202.

CHAP. V.

CONCERNING THE BILE, THE GASTRIC JUICE, AND THE ACID OBTAINED FROM ANTS.

ANIMAL FLUIDS.

THE fluids which remain to be conſidered, as compoſing part of animals, are the bile, the gaſtric juice, and ſuch acids as are obtained by treatment of animal matters.

Characters of the bile or gall.

The bile or gall is a fluid of a yellowiſh green colour, exceſſively bitter, and of a faint nauſeous ſmell. It is ſeparated from the blood in a glandular viſcus, well known by the denomination of the liver, and in moſt animals is collected in a veſſel called the gall bladder. The gall of oxen is that which chemiſts have more particularly examined. Its conſiſtence is almoſt gelatinous; by agitation it forms a froth ſimilar to that of a ſolution of ſoap. Water diſſolves it in all proportions; and this ſolution produces the ſame effect as a ſolution of ſoap in ſcouring cloths. All the acids decompoſe it, and produce a coagulum, which ſeparates from the watery ſolution, at the ſame time that the acid becomes neutralized by a portion of mineral alkali which unites with it. The coagulum, which may be ſeparated by the filter, is thick, viſcid, very bitter, and very inflammable. It appears ſo far of a reſinous nature, as to be totally ſoluble in ardent ſpirit: hence it follows that the bile conſiſts principally of a ſoap compoſed of this matter, and the mineral alkali. It alſo contains a quantity of ſerum, which cauſes it to coagulate by heat, or by the action of ardent ſpirit, and diſpoſes it to putrefy. Ardent ſpirit takes up the ſaponaceous matter, and leaves the ſerum behind.

Deſtructive diſtillation of the bile.

Deſtructive diſtillation ſeparates firſt an aqueous fluid, neither acid nor alkaline, but diſpoſed to putrefy. Nothing elſe paſſes over upon the water-bath. The reſidue is of a dark colour, very tenacious, like pitch, and totally ſoluble in water. If the diſtillation be continued with caution, on account of the ſwelling of the matter, the products are a yellowiſh alkaline phlegm, empyreumatic oil, much volatile alkali, and the elaſtic products conſiſt of fixed and inflammable air. A conſiderable coal remains, which contains mineral alkali, an earth, which is probably a combination of phoſphoric acid and lime, and a ſmall portion of iron.

Biliary concretions.

The nature of the biliary concretions which are formed in the gall bladder, has not yet been completely aſcertained. Theſe are found ſometimes of an irregular texture, and a brown, black, yellowiſh, or greeniſh colour; others conſiſt of tranſparent cryſtalline laminæ, ſometimes radiated from the centre to the circumference. * Two ounces of biliary calculus, of a grey colour without, and browniſh green within, were diſſolved in twelve times their weight of pure ardent ſpirit, by the aſſiſtance of a moderate heat. The hot ſolution being filtered, ſoon depoſited, by cooling, a large quantity of laminated white brilliant cryſtals, reſembling the concrete acid of borax. The

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* Fourcroy, in the Annales de Chimie, iii. 245.

quantity

Examination of the biliary calculus.

quantity amounted to near one ſixteenth of the whole calculus; and, upon examination, it poſſeſſed the following properties:—It was inflammable, and melted by a gentle heat in a ſpoon, with a ſmell like wax, and cooled into a brittle ſubſtance of a cryſtallized fracture: a ſudden heat volatilized the whole. Water had no action upon it when cold; but boiling water cauſed it to melt, and float on the ſurface like an oil, which became concrete by cooling. Cauſtic alkalis converted it into ſoap. Nitrous acid diſſolved it quietly, and the addition of water ſeparated it unaltered. Ardent ſpirit diſſolved it by heat; but the greateſt part was ſeparated by cooling. Theſe characters indicate that it is a ſubſtance of the ſame nature as ſpermaceti. The author * of this valuable diſcovery has alſo found that the cryſtallized gall ſtones contain this matter ſtill more abundantly; and that it exiſted in conſiderable quantity in an human liver which had been expoſed to the air for ſeveral years, and had loſt its volatile parts by putrefaction. The aſſiduous reſearches of the ſame philoſopher into the animal œconomy, have detected the ſame ſubſtance, in a ſaponaceous form, in bodies which had been many years buried under ground.

The gaſtric fluid.

A conſiderable number of chemiſts have examined the properties of the fluid which appears to be the menſtruum of digeſtion in the ſtomachs of animals. It is certain that in this proceſs the aliments become converted into a ſoft or pulpy maſs, moſt probably by the action of a ſolvent, aſſiſted by their own tendency

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* Fourcroy, in the Annales before cited, iii. 120.

The gaſtric fluid.

ſpontaneous decompoſition, at the temperature of e body of the animal. The gaſtric juice procured om the ſtomachs of animals which have been kept ſting for a conſiderable time, appears to differ according to their reſpective natures. It is thought to oſſeſs a ſolvent power upon animal and vegetable bſtances, without any preference of affinity; but is laſt circumſtance is ſcarcely probable. A powerl antiſeptic quality is reckoned among its attributes; at there are ſome reaſons to think that in graminivoous animals it has the contrary effect. In theſe laſt, ore eſpecially, it contains a diſengaged acid, which ems to be the phoſphoric. And upon the whole, it pears that accurate and deciſive experiments are ſtill anting, to determine the nature of this compounded nd variable fluid, which is of ſuch important uſe in e animal œconomy.

Acid of ants.

Of the acids which are conſidered as belonging ore eſpecially to the animal kingdom, we have ready attended to thoſe afforded by milk, by fat, y the ſtone of the bladder, by ſilk worms, and by e calcination of blood with an alkali, in the preparation of Pruſſian blue; it therefore remains only for to give an account of the acid which is afforded by ts. Theſe animals appear to contain a peculiar id, in a veſſel placed near the hinder part of their dies *, which they eject when enraged; or moiſten eir fangs with it, to render their bite more painful. he acid may be obtained by diſtillation of the ants

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* Wiegleb's Chemiſtry, by Hopſon, p. 191. On this acid, nſult the authors there referred to; and alſo Fontana, in the urnal de Phyſique for 1778, part ii.

with

ANIMAL FLUIDS.

Acid of ants.

with water, and ſubſequent preſſure of the reſidue; or the ants may be tied up in a bag, and twice infuſed in hot water; from which infuſion as much acid may be diſtilled off as can be had without burning the reſidue. It may be purified by ſaturating it with alkali, filtrating, and evaporating part of the liquor, and diſtilling it with half its weight of vitriolic acid: or, more conveniently, the rectified acid may be expoſed to the action of a freezing atmoſphere, which congeals its aqueous part. This acid has a conſiderable reſemblance to vinegar when it is diluted. It acts upon, and combines with, alkalis, ſoluble earths, and metals, and forms peculiar compounds; from which, as well as the order of its elective attractions, its title to be conſidered as a diſtinct or peculiar acid is eſtabliſhed.

Deſtructive diſtillation converts it, like the vegetable acids, into fixed air and inflammable air.

A P P E N D I X.

VARIOUS TABLES USEFUL TO CHEMISTS.

AN ACCOUNT OF THE TABLES.

ACCOUNT OF TABLES.

Table of comparative heats.

TABLE I. contains a ſeries of numbers, expreſſing the comparative heats of bodies. It is copied from Crawford's Experiments and Obſervations on Animal Heat, and the Inflammation of Combuſtible Bodies: London, 1788. The principles on which this Table is formed, have been explained in page 14 of our Work, and elſewhere. Nothing more need therefore be ſaid, than that the numbers are here reduced to one common ſtandard of compariſon, water being aſſumed as unity. As theſe numbers are deduced from the thermometrical changes undergone by the ſeveral bodies in like ſituations, it is clear that they are of uſe to indicate thoſe changes, for they will be inverſely as the numbers themſelves.

Table of weights.

TABLE II. contains the weights of different countries, compared in French and Engliſh grains. The value of this Table is obvious, and its character may be ſeen at page 70.

Table of ſpecific gravities.

TABLE III. exhibits the ſpecific gravities of bodies. In compiling this, I had Briſſon's Table at the end of Lavoiſier's Traité Elementaire de Chimie, and Muſchenbroek's large Table in his Cours de Phyſique, before me. Some few ſpecific gravities are from other authors, or from experiment. It appeared uſeleſs to carry it to more than four places of figures, as the temperatures were not noted, and the various ſpecimens of the ſame ſubſtance often differ in the third figure. Theſe aſſertions may be thought to require proof: for which reaſon I ſhall obſerve, that by experiment I find that the fifth figure changes at every three degrees of Fahrenheit's thermometer; that lead, tin, and probably all other metals caſt out of the ſame fuſion, vary in their ſpecific gravities in the third figure, from circumſtances not yet determined, but moſt likely from the cooling, as is ſeen in the hardening of ſteel; that ſalts, and other artificial preparations, retain more or leſs of the ſolvent they were ſeparated from, according to the temperature at which it was effected; and that all parts of organized ſubſtances not only differ according to the place of their production, their age, and other circumſtances, but likewiſe from their dryneſs, moiſture, and manner of preſervation.

Table of ſpecific gravities of aerial fluids.

TABLE IV. is taken from the ſeventh Table of M. Lavoiſier's Traité Elementaire. I have in another place * mentioned the ſtrong objections which may be urged againſt the ſuppoſed or implied accuracy of theſe weights, taken to ſo many places of figures. In that place, as the object of attention was of a controverſial nature, it was proper to ſpeak far within compaſs; but on the preſent occaſion I muſt obſerve, that the moſt accurate practical chemiſts would conſider a true determination of the ſpecific gravities of aerial fluids to three, or even two places of figures, as a great and valuable acquiſition; and though I regard this Table as the beſt we poſſeſs, yet in every inſtance I doubt the accuracy of the third decimal, and in moſt of them the ſecond. The column of Engliſh grains is ſubſtituted inſtead of the weight of a cubic foot French, which occupies that place in the original.

Table of expanſions of airs.

TABLE V. is taken from an excellent Paper of Morveau, in the firſt volume of the Annales de Chimie. The experiments were made by M. Prieur du Vernois upon the quantity of about 15½ cubic inches French, under the preſſure of about 27 French inches of mercury, which anſwer to near 28 Engliſh. The manner in which this inveſtigation was conducted, does great credit to both the philoſophers who were concerned in it; and the Eſſay itſelf, of which this Table is the reſult, is highly deſerving of the attention of thoſe

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* Preface to the ſecond edition of Kirwan's Eſſay on Phlogiſton, p. x.

ſtudents who wiſh to know the precautions required in theſe delicate experiments, as well as of the ſtrict enquirer who may be deſirous of knowing how far he may depend on the Table itſelf.

Tables of elective attractions.

TABLES VI. to XI. contain in ſubſtance the two Tables of Attractiones Electivæ Simplices which are placed at the end of Bergman's Treatiſe on Elective Attractions, inſerted in the third volume of his Opuſcula, and of which we have had a ſeparate tranſlation into Engliſh. They have been ſince copied into a variety of works, and in moſt with amendments. I have not however ventured to make any alteration, except ſuch as tended to facilitate the inſertion of them in the regular pages of the book, inſtead of adopting the much leſs convenient mode of printing on a large ſheet to be folded out. Hence it is the arrangement of the columns only which is altered, and repetitions avoided; except that in Table VIII. there is a notice that the perlate acid, vital air, the matter of heat, and ſiderite, are left out; the reaſons for which need not be repeated here. Two inducements rendered it moſt eligible to retain the Tables, in other reſpects, the ſame as Bergman left them: The one was, that they might continue to be Bergman's Tables; and the other was, that, if I had been prepared for the arduous taſk of compoſing new Tables, it would have been incumbent on me to have fully ſtated my reaſons for the arrangements I might have adopted; which would have been incompatible with the limits of an Elementary Treatiſe.

With regard to theſe Tables, after earneſtly recommending the ſtudent to peruſe the work from which they are extracted, it may be obſerved, that the ſubſtances at the heads of the columns are conſidered as ſimple, with regard to the facts enumerated in theſe ſketches, and ſo likewiſe are the ſubſtances inſerted in the columns. The order of poſition denotes that the higher any ſubſtance ſtands in any column, the ſtronger is its elective attraction to the ſubſtance at the head of that column. The under part of each Table exhibits the attractions in the dry way, and muſt be conſidered as entirely diſtinct from the upper part. The horizontal lines between the ſubſtances in the columns denote that their poſitions, or comparative powers of attraction, are well determined; and, whenever theſe lines are wanting, the poſitions are more or leſs conjectural. Hence it may be ſeen how much remained to be done at the time the great Bergman conſtructed theſe Tables.

ACCOUNT OF TABLES.

Elective attractions.

TABLE XII. exhibits an approximation towards expreſſing the powers of elective attraction between bodies generally applied. It is evident that the Tables of ſimple elective attraction expreſs only the order in which the ſeveral enumerated ſubſtances ſurpaſs each other in power to adhere to the common ſubſtance at the head of each column; and do not by any means ſhew what will happen when a compound of two principles is applied to another compound alſo containing two principles, as in the caſes called double elective attraction. We cannot, in fact, decide in circumſtances of this nature, unleſs we are previouſly acquainted with the ſum of the two attractions which tend to preſerve the original combinations, and are on that account very expreſſively

denomi-

ACCOUNT OF TABLES.

denominated by Mr. Kirwan quieſcent attractions; and alſo with the ſum of the other two attractions which tend to form new combinations, and are by the ſame chemiſt called the divellent attractions. Thus, for example, if vitriolated tartar, or the compound of vegetable alkali and vitriolic acid, be preſented to the marine ſalt of lime, we cannot foretel the conſequence from any ſimple Tables, becauſe theſe will not ſhew whether the ſum of the powers which tend to preſerve the union of the alkali and vitriolic acid, and alſo of the lime and marine acid, be in fact greater or leſs than thoſe by which the alkali tends to combine with the marine, and the lime with the vitriolic acid, and form the new compound of ſalt of ſylvius and ſelenite. Hence we ſee the great advantage which the ſcience of chemiſtry would derive from an extenſive numerical Table founded on experiments of the nature of that now before us. For, in the preſent inſtance, we find from the Table, that the vegetable alkali and vitriolic acid adhere with a power expreſſed by the number 62; while the lime and marine acid adhere with a power denoted by 20. Theſe are the quieſcent affinities, and their ſum is 82. On the other hand, by the ſame Table, we find that the attraction between vitriolic acid and lime is 54; and between vegetable alkali and marine acid 32. Theſe are the divellent affinities, and their ſum is 86. The latter muſt therefore prevail; that is, the combinations will be changed by the vitriolic acid melting with the lime, and forming ſelenite; while the marine acid combines with the vegetable alkali, and forms ſalt of ſylvius.

ACCOUNT OF TABLES.

Table of ingredients in earths and ſtones.

TABLE XIII. ſhews the proportion of ingredients in earths and ſtones. It is taken from Kirwan's Mineralogy. The extenſive and indefatigable reſearches of this author into all the ſources of chemical information, and the numerous additions he has himſelf made to the ſcience, have enabled him to render this Table more perfect than any which is elſewhere to be met with. Much however remains ſtill to be done, in every part of it, before we can depend on its accuracy throughout; and we hope the author will add the labour of perfecting it, to the other advantages which the ſcientific world has derived from his exertions.

TABLE I. The Comparative Heats of different Bodies.

Inflammable air	21.4000
Dephlogiſticated air	4.7490
Atmoſpherical air	1.7900
Aqueous vapour	1.5500
Fixed air	1.0454
Arterial blood	1.0300
Water	1.0000
Freſh milk of a cow	.9999
Venous blood	.8928
Phlogiſticated air	.7936
Hide of an ox, with the hair	.7870
Lungs of a ſheep	.7690
Lean of the beef of an ox	.7400
Alcohol	.6021
Rice	.5060
Horſe beans	.5020
Spermaceti oil	.5000
Duſt of the pine tree	.5000
Peas	.4920
Wheat	.4770
Barley	.4210
Oats	.4160
Vitriolic acid	.4290
Pitcoal	.2777
Charcoal	.2631
Chalk	.2564
Ruſt of Iron	.2500
Waſhed diaphoretic antimony	.2272
Calx of copper, nearly freed from air	.2272
Quicklime	.2229
Cinders	.1923
Aſhes of cinders	.1855
Ruſt of iron, nearly freed from air	.1666
Waſhed diaphoretic antimony, nearly freed from air	.1666
Aſhes of the elm-tree	.1402
Calx of zinc, nearly freed from air	.1369
Iron	.1269
Braſs	.1123
Copper	.1111
White calx of tin, nearly freed from air	.0990
Regulus of zinc	.0943
Aſhes of charcoal	.0909
Tin	.0704
Yellow calx of lead, nearly freed from air	.0680
Regulus of antimony	.0645
Lead	.0352

TABLE II. The Weights of different Countries.

Place and Denomination of Weight.	Marc	oz.	gros.	grains.	F. grains.	E. grains.
Berlin. The marc of 16 loths		7	5	16	4408	3616.3
Berne. Goldſmiths weight of 8 ounces	1	—	½	4	4648	3813.2
Berne. Pound of 16 ounces, for merchandiſe	2	1	½	6	9834	8067.7
The common pound varies very conſiderably in other towns of the Canton.						
Berne. Apothecaries weight of 8 ounces	—	7	5½	26	4454	3654.
Bonn.	—	7	5	6¾	4308¾	3608.6
Bruſſels. The marc, or original troyes weight	1	—	—	21	4629	3797.6
Cologn. The marc of 16 loths	—	7	5	11	4403	3612.2
Conſtantinople. The cheki, or 100 drachms	1	2	3	28	6004	4925.6
Copenhagen. Goldſmiths weight, commonly ſuppoſed equal to the marc of Cologn	—	7	5½	10⅓	4438⅓	3641.2
Copenhagen. Merchants weight of 16 loths	1	—	1	22½	4702½	3857.9
Dantzick. Weight commonly ſuppoſed equal to the marc of Cologn	—	7	5	3½	4395½	3606.
Florence. The pound (anciently uſed by the Romans)	1	3	½	20	6392	5244.
Genoa. The peſo ſottile	1	2	2½	30	5970	4897.7
Genoa. The peſo groſſo	1	2	3	5	5981	4906.7
Hamburgh. Weight; commonly ſuppoſed equal to the Cologn marc	—	7	5	7¾	4399¾	3609.4
Hamburgh. Another weight	—	7	7	23	4559	3740.2
Liege. The Bruſſels marc uſed; but the wt. proved	1	—	—	24	4632	3800.1
Liſbon. The marc, or half pound	—	7	3½	34	4318	3542.4
London. The pound troy	1	4	1½	1	7021	5760.
London. The pound avoirdupoiſe	1	6	6½	6.	8538	7004.5
Lucca. The pound	1	3	—	23¼	6359¼	5217.
Madrid. The marc royal of Caſtile	—	7	4	8	4328	3550.7
Malta. The pound	1	2	2½	21	5961	4890.4
Manheim. (The Cologn marc).	—	7	5	10¼	4402¼	3611.5
Milan. The marc	—	7	5	33	4425	3630.2
Milan. The libra groſſa	3	—	7½	—	14364	11784.
Munich (The Cologn marc)	—	7	5	11½	4403½	3612.3
Naples. The pound of 12 ounces	1	2	3½	27.	6039	4954.3
Ratiſbon. The weight for gold; of 128 crowns	1	6	—	24	8088	6635.3
Ratiſbon. The weight for ducats; of 64 ducats	—	7	2	32	4208	3452.3
Ratiſbon. The marc of 8 ounces	1	—	—	24	4632	3800.1
Ratiſbon. The pound of 16 ounces	2	2	4½	6	10698	8776.5
Rome. The pound of 12 ounces	1	3	½	14	6386	5239.
Stockholm. The pound of 2 marcs	1	5	7	8	8000	6563.1
Stuttgard. (The Cologn marc)	—	7	5	11¾	4403¾	3612.6
Turin. The marc of 8 ounces	1	—	—	22¼	4630¼	3799.
At Turin they have alſo a pound of 12 of the above ounces. But, in their apothecaries pound of 12 ounces, the ounce is one ſixth lighter.						
Warſaw. The pound	1	5	2	12	7644	6271.
Venice. The libra groſſa of 12 ounces	1	7	4½	25½	8989½	7374.5
Venice. The peſo ſottile of 12 ounces	1	1	6½	24	5676	4656.5
In the towns dependant on Venice, the pound differs conſiderably in each.						
Vienna. The marc of commerce	1	1	1	16	5272	4325.
Vienna. The marc of money	1	1	1	26	5282	4333.3
France. The grain	—	—	—	—	1.	1.21895
England. The grain	—	—	—	—	0.82039	1.

TABLE III. The Specific Gravities of Bodies.

Pure gold caſt	19258
——— hammered	19362
Standard gold caſt	17486
——— hammered	17589
Pure ſilver caſt	10474
——— hammered	10511
Standard ſilver in coin	10391
Crude platina in grains	15602
Platina purified and fuſed	19500
——— hammered	20337
——— drawn into wire	21042
——— laminated.	22069
Mercury	13568
Lead fuſed	11352
Copper fuſed	7788
——— drawn into wire	8878
Braſs caſt	8396
——— in wire	8544
Iron caſt	7207
——— bar	7788
Steel, ſoft and not hammered	7840
——— hardened	7816
Tin, Engliſh, fuſed	7291
——— hammered	7299
Malacca tin fuſed	7296
——— hammered	7306
Biſmuth	9823
Nickel	8660
Arſenic, the regulus	5763
Cobalt	7812
Zinc	7191
Antimony	6702
Manganeſe	6850
Wolfram	17600
Diamond	3521
Ruby	4283
——— ſpinell	3760
Topaz, oriental	4011
——— Brazilian	3536
——— Saxon	3564
Sapphire, oriental	3994
Emerald	2775
Adamantine ſpar	4180
Jargon of Ceylon	4615
Rock cryſtal from Madagaſcar	2653
Quartz	2654
Agate	2590

Onyx	2637
Muſcovy talc	2792
Common ſlate	2672
Calcareous ſpar	2715
Alabaſter	2730
White marble	2716
Lime ſtones from	1386
——— to	2390
Ponderous ſpar	4474
Fluor ſpar	3180
Pumice ſtone	914
Green glaſs	2620
Engliſh crown glaſs	2520
White flint glaſs, Engliſh	3290
Another piece	3216
White flint glaſs, for achromatic uſes	3437
White glaſs, French	2892
Glaſs of S.ᵗ Gobin	2488
Brimſtone	1990
Phoſphorus	1714
Yellow amber	1078
Diſtilled water	1000
Sea water	1026
Common ſpirit of wine	837
Spirit of wine, the pureſt which can be had by mere diſtillation	820
Vitriolic ether	739
Nitrous	909
Marine	730
Acetous	866
Concentrated vitriolic acid	2125
——— nitrous acid	1580
——— marine acid	1194
Fluor acid	1500
Oil of olives	915
— of ſweet almonds	917
Linſeed oil	940
Naptha	708
Gum elaſtic	933
Camphor	989
Yellow wax	965
White Do.	969
Spermacceti	943
Tallow	942
Heart of oak	1170
Cork	240
Egg new laid	1081

TABLE IV. The Specific Gravities of Aerial Subſtances; the Barometer ſtanding at 30 Inches, and the Thermometer at + 55°.*

Names of Aerial Subſtances.	Weight of one cubic Inch. French.	Weight of one cubic Inch. Engliſh.	From the Experiments of
	French grains.	Engliſh grains.	
Atmoſpheric air	0.46005	0.45689	M. Lavoiſier.
Phlogiſticated air	0.44444	0.44139	The ſame.
Vital air	0.50694	0.50346	The ſame.
Inflammable air	0.03539	0.03515	The ſame.
Fixed air	0.68985	0.68511	The ſame.
Nitrous air	0.54690	0.54314	M. Kirwan.
Alkaline air	0.27488	0.27299	The ſame.
Vitriolic air	1.03820	1.03109	The ſame.

* Strictly the numbers are 29.84 inches and 54.5 degrees; anſwering to 28 French inches, and 10 deg. of Reaumur.

TABLE V. The Expanſions of Aerial Subſtances by Heat, from the Freezing to the Boiling Points of Water. For every Interval of 20° of Reaumur's, or 45° of Fahrenheit's Thermometer.

Names.	From 32° to 77°	From 77° to 122°	From 122° to 167°	From 167° to 212°	Total From 32° to 212°
Common air	$\frac{1}{12.87}$	$\frac{1}{5.61}$	$\frac{1}{2.49}$	[$\frac{1}{3.63}$]	$\frac{1}{1.067}$
Vital air	$\frac{1}{22.12}$	$\frac{1}{4.92}$	$\frac{1}{1.53}$	[$3+\frac{1}{1.73}$]	$4+\frac{1}{2.09}$
Phlogiſt. air	$\frac{1}{29.41}$	$\frac{1}{6.41}$	$\frac{1}{1.82}$	[$5+\frac{1}{57.2}$]	$5+\frac{1}{1.062}$
Inflam. air	$\frac{1}{11.91}$	$\frac{1}{6.92}$	[$\frac{1}{7.83}$]	[$\frac{1}{18.82}$]	$\frac{1}{2.65}$
Nitrous air	$\frac{1}{16.33}$	$\frac{1}{9.00}$	$\frac{1}{3.739}$	[$\frac{1}{6.88}$]	$\frac{1}{1.63}$
Fixed air	$\frac{1}{9.049}$	$\frac{1}{5.099}$	$\frac{1}{2.31}$	[$\frac{1}{3.69}$]	$1+\frac{1}{107.7}$
Alkaline air	$\frac{1}{3.68}$	$\frac{1}{1.73}$	$1+\frac{1}{1.35}$	[$3+\frac{1}{4.69}$]	$5+\frac{1}{5.248}$

*** The numbers between brackets are uncertain.

TABLE VI. Simple Elective Attractions.

ACIDS.

VITRIOLIC ACID.	NITROUS ACID.	MARINE ACID.	FIXED AIR.	ACID OF BORAX.	ACID OF AMBER.	ACETOUS ACID DISTILLED.
Barytes	Veg. alkali ?	Veg. alkali ?	Barytes	Lime	Barytes	Barytes
Veg. alkali	Min. alkali ?	Min. alkali ?	Lime	Barytes	Lime	Veg. alkali
Min. alkali	Barytes ?	Barytes ?	Veg. alkali	Magneſia	Magneſia	Min. alkali
Lime	Lime	Lime	Min. alkali	Veg. alkali	Veg. alkali	Vol. alkali
Magneſia	Magneſia	Magneſia	Magneſia	Min. alkali	Min. alkali	Lime
Vol. alkali	Vol. alkali	Vol. alkali	Vol. alkali	Vol. alkali	Vol. alkali	Magneſia
Clay	Clay	Clay	Clay	Clay	Clay	Clay
Metallic calces	Metallic calces	Metallic calces	Metallic calces	Metallic calces	Metallic calces	Metallic calces
Water	Water	Water	Water	Water	Water	Water
Ardent ſpirit	Ardent ſpirit	Ardent ſpirit	Ardent ſpirit	Ardent ſpirit	Ardent ſpirit	Ardent ſpirit
Phlogiſton	Phlogiſton	Phlogiſton		Phlogiſton	Phlogiſton	Phlogiſton
N. B. The ſulphureous or volatile vitriolic acid follows the ſame order in the humid way.	N. B. The fuming nitrous acid follows the ſame order in the humid way.	N. B. The dephlogiſticated or aerated marine acid follows the ſame order in the humid way.	In the DRY WAY.	N. B. The ſame order is followed by the acids of ſugar or ſorrel; tartar; and lemon.	The order in which the metallic calces precipitate each other in acids, is the reverſe of that in the column of phlogiſton, in Table IX. Conſult page 132.	
Phlogiſton	Phlogiſton	Phlogiſton	PRUSSIAN ACID.			
Veg. alkali	Barytes	Barytes	In the HUMID WAY.	Lime	Barytes	Barytes
Min. alkali	Veg. alkali	Veg. alkali	Veg. alkali	Barytes	Lime	Veg. alkali
Barytes	Min. alkali	Min. alkali	Min. alkali	Magneſia	Magneſia	Min. alkali
Lime	Lime	Lime	Vol. alkali	Veg. alkali	Veg. alkali	Lime
Magneſia	Magneſia	Magneſia	Lime	Min. alkali	Min. alkali	Magneſia
Metallic calces	Metallic calces	Metallic calces	Barytes	Metallic calces	Metallic calces	Metallic calces
Vol. alkali	Vol. alkali	Vol. alkali	Magneſia	Vol. alkali	Vol. alkali	Vol. alkali
Clay	Clay	Clay	Clay	Clay	Clay	Clay
		N. B. Aqua regia follows the ſame order both in the humid and dry way.	Metallic calces	N. B. The ſame order both in the humid and dry way is followed by the acids of ſpar; of arſenic; of benzoin; of ſugar of milk; of fat; and of phoſphorus: except that phlogiſton occupies the firſt place in the dry way with the arſenical acid.		N. B. The ſame order both in the humid and dry way is followed by the acids of milk and of ants.
			Water			

TABLE VII. Simple Elective Attractions.

ALKALIS AND EARTHS.

IN THE HUMID WAY.

VEG. ALKALI	MIN. ALKALI	CLAY.	LIME.	BARYTES.	MAGNESIA.
Vitriolic acid	This alkali agrees with the vegetable in the order of its attractions, both in the humid and the dry way.	Vitriolic acid	A. of ſugar	Vitriolic acid	Acid of ſugar
Nitrous acid		Nitrous a.	Vitriolic a.	A. of ſugar	Phoſphor. a.
Marine acid		Marine a.	A. of tartar	A. of amber	Vitriolic acid
Acid of fat		A. of ſugar	A. of amber	A. of ſpar	A. of ſpar
Acid of ſpar		Arſenical a.	Phoſphor. a.	Phoſphor. a.	A. of fat
Phoſphor. acid		Sparry a.	A. of ſ. of milk	A. of ſ. of milk	A. of arſenic
A. of ſugar		A. of fat	Nitrous acid	Nitrous acid	A. of ſ. of milk
A. of tartar		A. of tartar	Marine acid	Marine acid	A. of amber
A. of arſenic		A. of amber	A. of fat	A. of fat	Nitrous acid
A. of amber		A. of ſ. of milk	A. of ſpar	A. of lemon	Marine acid
A. of lemon		A. of lemon	A. of arſenic	A. of tartar	A. of tartar
A. of ants	VOL. ALKALI.	Phoſphor. a.	A. of ants	A. of arſenic	A. of lemon
A. of milk		A. of ants	A. of milk	A. of ants	A. of ants
A. of benzoin	This alkali agrees with the vegetable in the order of its attractions, both in the humid and dry way: but mere heat expels it from the acids of phoſphorus, borax, and arſenic.	A. of milk	A. of lemons	A. of milk	A. of milk
Acetous acid		A. of benzoin	A. of benzoin	A. of benzoin	A. of benzoin
A. of ſ. of milk		Acetous acid	Acetous acid	Acetous acid	Acetous acid
Acid of borax		A. of borax	Acid of borax	Acid of borax	A. of borax
Vol. vitr. a.		Vol. vitr. a.	Vol. vitr. a.	Vol. vitr. a.	Vol. vitr. a.
Fuming nitr. a		Fum. nitr. a.	Fum. nitr. a.	Fum. nitr. a.	Fum. nitr. a.
Fixed air		Fixed air	Fixed air	Fixed air	Fixed air
Pruſſian acid		Pruſſian acid	Pruſſian a.	Pruſſian a.	Pruſſian a.
Water			Water	Water	
Fat oils			Fat oils	Fat oils	
Sulphur			Sulphur	Sulphur	Sulphur
Met. calces					

IN THE DRY WAY.

Phoſphor. acid	SILEX.	Phoſphor. acid	Phoſphor. acid	Phoſphor. acid	Phoſphor. acid
A. of borax		A. of borax	A. of borax	A. of borax	A. of borax
A. of arſenic	In the HUMID WAY.	A. of arſenic	A. of arſenic	A. of arſenic	A. of arſenic
Vitriolic acid		Vitriolic acid	Vitriolic acid	Vitriolic acid	Vitriolic acid
Nitrous acid	A. of ſpar	Nitrous acid	A. of amber	A. of amber	A. of ſpar
Marine acid	Veg. alkali	Marine acid	Nitrous acid	Acid of ſpar	A. of fat
A. of fat		A. of ſpar	Marine acid	Nitrous acid	A. of amber
A. of ſpar		A. of fat	A. of fat	Marine acid	Nitrous acid
A. of amber	In the DRY WAY	A. of amber	A. of ſpar	A. of fat	Marine acid
A. of ants	Fixed alkali	A. of ants	A. of ants	A. of ants	A. of ants
A. of milk	Phoſphor. acid	A. of milk	A. of milk	A. of milk	A. of milk
A. of benzoin	Calx of lead	A. of benzoin	A. of benzoin	A. of benzoin	A. of benzoin
Acetous acid		Acetous acid	Acetous acid	Acetous acid	Acetous acid
Barytes		Fixed alkali	Fixed alkali	Fixed alkali	Fixed alkali
Lime		Sulphur	Sulphur	Sulphur	Sulphur
Magneſia		Calx of lead	Calx of lead	Calx of lead	Calx of lead
Clay					
Silex					
Sulphur					

TABLE VIII. Simple Elective Attractions.

COMBUSTIBLE SUBSTANCES AND WATER.

IN THE HUMID WAY.

WATER.	SULPHUR.	SALINE LIVER OF SULPHUR.	ARDENT SPIRIT	ETHER.
Veg. alkali	Calx of lead	Calx of gold	Water	Ardent ſpirit
Min. alkali	C. of tin	C. of ſilver	Ether	Eſſential oils
Vol. alkali	C. of ſilver	C. of mercury	Eſſential oils	Expreſſed oils
Ardent ſpirit	C. of mercury	C. of arſenic	Volatile alkali	Water
Mild vol. alk.	C. of arſenic	C. of antimony	Fixed alkali	Sulphur
Glauber's ſalt	C. of antimony	C. of biſmuth	Saline hepar	
Ether	C. of iron	C. of copper	Sulphur	
	Veg. alkali	C. of tin		
	Vol. alkali	C. of lead		
	Barytes	C. of nickel	EXPRESSED OIL	ESSENTIAL OIL
	Lime	C. of cobalt		
	Magneſia	C. of manganeſe		
Vitriolic acid		C. of iron	Ether	Ether
Vitriolated tartar	Fat oils		Eſſential oils	Ardent ſpirit
Alum	Eſſential oils	Ardent ſpirit	Fixed alkalis	Fat oils
Martial vitriol	Ether	Water	Vol. alkali	Fixed alkalis
Corroſ. ſublimate	Ardent ſpirit		Sulphur	Sulphur

IN THE DRY WAY.

Fixed alkali	Manganeſe
Iron	Iron
Copper	Copper
Tin	Tin
Lead	Lead
Silver	Silver
Cobalt	Gold
Nickel	Antimony
Biſmuth	Cobalt
Antimony	Nickel
Mercury	Biſmuth
Arſenic	Mercury
	Arſenic

Four of the columns in the original tables of Bergman are omitted in theſe, viz.

The perlate acid; for which ſee page 209.

Vital air, which is ſuppoſed to have an affinity to phlogiſton only.

The matter of heat; for which ſee pages 6. 21.

The ſemimetal ſiderite; for which ſee page 313.

TABLE IX. Simple Elective Attractions;

PHLOGISTON AND METALS.

IN THE HUMID WAY.

Phlogiston	Calx of Gold	C. of Silver	C. of Platina	C. of Mercury.	C. of Lead.
Nitrous acid	Ether	Marine acid	Ether	Acid of fat	Vitriolic acid
Vitriolic acid	Marine acid	Acid of fat	Marine acid	Marine acid	Acid of fat
Dephl. marine a.	Aqua regia	Acid of ſugar	Aqua regia	Acid of ſugar	A. of ſ. of milk
Arſenical acid	Nitrous acid	Vitriolic acid	Nitrous acid	Acid of amber	A. of ſugar
Phoſphor. acid	Vitriolic acid	A. of ſ. of milk	Vitriolic acid	Arſenical acid	Arſenical acid
	Arſenical acid	Phoſphor. acid	Arſenical acid	Phoſphor. acid	Acid of tartar
C. platina	Sparry acid	Nitrous acid	Sparry acid	Vitriolic acid	Phoſphor. acid
C. gold	Acid of tartar	Arſenical acid	Acid of tartar	A. of ſ. of milk	Marine acid
C. ſilver	Phoſphor. acid	Sparry acid	Phoſphor. acid	Acid of tartar	Nitrous acid
C. mercury	Acid of fat	Acid of tartar	Acid of fat	Acid of lemon	Sparry acid
C. arſenic	Pruſſian acid	Acid of lemon	Acid of ſugar	Nitrous acid	Acid of lemons
C. antimony		Acid of ants	Acid of lemons	Sparry acid	Acid of ants
C. biſmuth		Acid of milk	Acid of ants	Acetous acid	Acid of milk
C. copper		Acetous acid	Acid of milk	Acid of borax	Acetous acid
C. tin		Acid of amber	Acetous acid	Pruſſian acid	Acid of borax
C. lead		Pruſſian acid	Acid of amber	Fixed air	Pruſſian acid
C. nickel		Fixed air			Fixed air
C. cobalt	Fixed alkali				Fixed alkali
C. manganeſe	Vol. alkali	Vol. alkali			
C. iron					
C. zinc					
Water					

N. B. In the antiphlogiſtic theory, the column intitled *Phlogiſton* being taken in a reverſed order, will expreſs the elective attractions of *Vital air.*

IN THE DRY WAY.

	Gold.	Silver.	Platina.	Mercury.	Lead.
C. of platina	Mercury	Lead	Arſenic	Gold	Gold
C. gold	Copper	Copper	Gold	Silver	Silver
Acid of arſenic	Silver	Mercury	Copper	Platina	Copper
C. ſilver	Lead	Biſmuth	Tin	Lead	Mercury
C. mercury	Biſmuth	Tin	Biſmuth	Tin	Biſmuth
C. arſenic	Tin	Gold	Zinc	Zinc	Tin
C. antimony	Antimony	Antimony	Antimony	Biſmuth	Antimony
C. biſmuth	Iron	Iron	Nickel	Copper	Platina
C. copper	Platina	Manganeſe	Cobalt	Antimony	Arſenic
C. tin	Zinc	Zinc	Manganeſe	Arſenic	Zinc
C. lead	Nickel	Arſenic	Iron	Iron	Nickel
C. nickel	Arſenic	Nickel	Lead		Iron
C. cobalt	Cobalt	Platina	Silver		
C. manganeſe	Manganeſe		Mercury		
C. iron	Sa. liv. of ſulph.	S. l. of ſulph.	S. l. of ſulph.	S. l. ſulph.	S. l. ſulphur
C. zinc		Sulphur		Sulphur	Sulphur

TABLE X. Simple Elective Attractions.

METALLIC SUBSTANCES.

IN THE HUMID WAY.

Calx of Copper.	Calx of Iron.	Calx of Tin.	Calx of Bismuth.	Calx of Nickel.	Calx of Arsenic.
Acid of ſugar	Acid of ſugar	Acid of fat	Acid of ſugar	Acid of ſugar	Marine acid
Acid of tartar	Acid of tartar	Acid of tartar	Acid of arſenic	Acid of ſorrel	Acid of ſugar
Marine acid	Vitriolic acid	Marine acid	Acid of tartar	Marine acid	Vitriolic acid
Vitriolic acid	A. of ſ. of milk	Vitriolic acid	Phoſphor. acid	Vitriolic acid	Nitrous acid
A. of ſ. of milk	Marine acid	Acid of ſugar	Vitriolic acid	Acid of tartar	Acid of fat
Nitrous acid	Nitrous acid	Arſenical acid	Acid of fat	Nitrous acid	Acid of tartar
Acid of fat	Acid of fat	Phoſphor. acid	Marine acid	Acid of fat	Phoſphor. acid
Arſenical acid	Phoſphor. acid	Nitrous acid	Nitrous acid	Phoſphor. acid	Acid of ſorrel
Phoſphor. acid	Arſenical acid	Acid of amber	Fluor acid	Fluor acid	Fluor acid
Acid of amber	Sparry acid	Sparry acid		A. of ſ. of milk	A. of ſ. of milk
Sparry acid	Acid of amber	A. of ſ. of milk		Acid of amber	Acid of amber
Acid of lemon	Acid of lemons	Acid of lemons		Acid of lemon	Acid of lemon
Acid of ants	Acid of ants	Acid of ants		Acid of ants	Acid of ants
Acid of milk	Acid of milk	Acid of milk		Acid of milk	Acid of milk
Acetous acid	Acetous acid	Acetous acid		Acetous acid	Arſenical acid
Acid of borax	Acid of borax	Acid of borax		Arſenical acid	Acetous acid
Pruſſian acid	Pruſſian acid	Pruſſian acid		Acid of borax	
Fixed air	Fixed air			Pruſſian acid	Pruſſian acid
Fixed alkali		Fixed alkali		Aerial acid	
Vol. alkali		Vol. alkali		Volatile alkali	Volatile alkali
Fat oils					Unctuous oils
					Water

IN THE DRY WAY.

Copper.	Iron.	Tin.	Bismuth.	Nickel.	Arsenic.
Gold	Nickel	Zinc	Lead	Iron	Nickel
Silver	Cobalt	Mercury	Silver	Cobalt	Cobalt
Arſenic	Manganeſe	Copper	Gold	Arſenic	Copper
Iron	Arſenic	Antimony	Mercury	Copper	Iron
Manganeſe	Copper	Gold	Antimony	Gold	Silver
Zinc	Gold	Silver	Tin	Tin	Tin
Antimony	Silver	Lead	Copper	Antimony	Lead
Platina	Tin	Iron	Platina	Platina	Gold
Tin	Antimony	Manganeſe	Nickel	Biſmuth	Platina
Lead	Platina	Nickel	Iron	Lead	Zinc
Nickel	Biſmuth	Arſenic	Zinc	Silver	Antimony
Biſmuth	Lead	Platina		Zinc	
Cobalt	Mercury	Biſmuth			
Mercury		Cobalt			
Sal. liv. of ſulph.	S. l. of ſulphur	S. l. of ſulph.	S. l. of ſulph.	S. l. of ſulph.	S. l. of ſulph.
Sulphur	Sulphur	Sulphur	Sulphur	Sulphur	Sulphur

TABLE XI. Simple Elective Attractions.

METALLIC SUBSTANCES.

IN THE HUMID WAY.

Calx of Cobalt.	Calx of Zinc.	Calx of Antimony.	Calx of Manganese.	Calx of Wolfram.
Acid of ſugar	Acid of ſugar	Acid of fat	Acid of ſugar	Lime
Acid of ſorrel	Vitriolic acid	Marine acid	Acid of ſorrel	Vegetable alkali
Marine acid	Marine acid	Acid of ſugar	Acid of lemon	Volatile alkali
Vitriolic acid	Acid of ſ. of milk	Vitriolic acid	Phoſphoric acid	
Acid of tartar	Nitrous acid	Nitrous acid	Acid of tartar	
Nitrous acid	Acid of fat	Acid of tartar	Fluor acid	
Acid of fat	Acid of ſorrel	Acid of ſorrel	Marine acid	In the DRY WAY.
Phoſphoric acid	Acid of tartar	Acid of ſ. of milk	Vitriolic acid	Fixed alkali
Fluor acid	Phoſphoric acid	Phoſphoric acid	Nitrous acid	Lime
Acid of ſ. of milk	Acid of lemon	Acid of lemon	Acid of ſ. of milk	Calx of iron
Acid of amber	Acid of amber	Acid of amber	Acid of amber	Calx of manganeſe
Acid of lemon	Fluor acid	Fluor acid	Acid of fat	
Acid of ants	Arſenical acid	Arſenical acid	Arſenical acid	This column is additional. It is deduced from De Luyart's Analyſis.
Acid of milk	Acid of ants	Acid of ants	Acid of ants	
Acetous acid	Acid of milk	Acid of milk	Acid of milk	
Arſenical acid	Acetous acid	Acetous acid	Acetous acid	
Acid of borax	Acid of borax	Acid of borax		
Pruſſian acid	Pruſſian acid	Pruſſian acid	Pruſſian acid	
Aerial acid	Aerial acid	Aerial acid	Aerial acid	
Volatile alkali	Volatile alkali			

IN THE DRY WAY.

Cobalt.	Zinc.	Antimony.	Manganese.	Wolfram.
Iron	Copper	Iron	Copper	Iron
Nickel	Antimony	Copper	Iron	Silver
Arſenic	Tin	Tin	Gold	Tin
Copper	Mercury	Lead	Silver	Lead
Gold	Silver	Nickel	Tin	Antimony
Platina	Gold	Silver		Biſmuth
Tin	Cobalt	Biſmuth		Manganeſe
Antimony	Arſenic	Zinc		Gold
Zinc	Platina	Gold		Platina
	Biſmuth	Platina		
	Lead	Mercury		
	Nickel	Arſenic		
	Iron	Cobalt		
Saline liv. of ſulph.		Sal. liv. of ſulphur	Sal. liv. of ſulphur	
Sulphur		Sulphur		

TABLE XII. Numerical Expreſſion of Attractions by M. Morveau.

	Vitriolic Acid.	Nitrous Acid.	Marine Acid.	Acetous Acid.	Aerial Acid or Fix. Air.
Ponderous earth	65	62	36	29	14
Vegetable alkali	62	58	32	26	9
Mineral alkali	58	50	28	25	8
Lime	54	44	20	19	12
Volatile alkali	46	38	14	20	4
Magneſia	50	40	16	17	6
Argil. earth	40	36	10	15	2

TABLE XIII. Of the Proportion of Ingredients in Earths and Stones.

Calcareous Genus.

100 Parts.	Calcar.	Argill.	Silex.	Mag.	Wat.	Iron.
Calcareous ſpar -	55	- -	- -	—	11	—[a]
Gypſum - -	32	- -	- -	—	38	—[b]
Fluor - - -	57	- -	- -	—	—	—[c]
Tungſten - -	50	- -	- -	—	—	—[d]
Compound ſpar -	60	- -	- -	35	—	5[e]
Cruetzenwald ſtone	75	- -	- -	12	—	3[f]
Calcareous marle -	50to75	20to30	20to30	—	—	—[g]
Margodes - -	50	32	15	—	—	2
Stellated ſpar - -	66	- -	30	—	—	3
Calcareous grit or ſand ſtone	50	- -	- -	—	—	—[h]
Swine ſtone - -	95	- -	- -	—	—	—[i]
Pyritaceous limeſtone	75	14	- -	—	—	4[k]
Martial tungſten -	- -	- -	- -	—	—	50[l]

[a] And 34 fixed air. —— [b] And 30 vitriolic acid. —— [c] 43 acid and water. —— [d] 50 acid and iron. —— [e] Both earths mild. —— [f] Ditto. —— [g] And water. —— [h] Or more; remainder, ſilex, argill. and iron. —— [i] And petrol.; remainder, argill. and iron. —— [k] And 7 quartz and ſulphur, that is, 25 pyrites. —— [l] By the dry way only 30, and 50 tungſten.

Barytic or Ponderous Genus.

100 Parts.	
Mild barytes	78 Earth, 20 fixed air, 2 baroſelenite.
Baroſelenite	84 Earth, 13 vitriolic acid, and 3 water.
Hepatic ſtone	33 Baroſelenite, 33 ſilex, 22 alum, 7 gypſum, 5 petroleum.

Muriatic or Magneſian Genus.

100 Parts.	Silex.	Calc.	Magneſia.	Argill	Water.	Iron.
Mild magneſia - - -	—	—	48	—	22	—*
Keffekil - - -	50	—	50	—	—	—
Steatites - - -	80	—	17	2	—	1
Argillaceous ſteatites -	72	—	17	11	—	—
Chalk of Briançon -	70	—	17	11	—	—†
Soap rock - -	70	—	17	13	—	—
Aſbeſtos - - -	63	11	20	4	—	2‡
Martial aſbeſtos - -	62	12	13,7	1,7	—	10,6
Suber montanum - -	59	11	24	2,4	—	3,6‖
Amianthus - -	64	6,9	18,6	3,3	—	1,2§
Serpentine - -	45	—	23	18	12	3
Talc, Muſcovy - -	50	—	45	5	—	—

Talc, Venetian - - a larger portion of argill. and ſmaller of magneſia.

Note, The magneſia and calcareous earths are in a mild ſtate, in all the above ſtones.

* At a medium, and 30 fixed air.——† And 2 of talc.——‡ At a medium.——‖ At a medium.——§ And 6 barytes.

Argillaceous Genus.

100 Parts.	Silex.	Argill	Calcareous	Magneſia.	Iron.	Water.
Pure clay, dry -	63	37*	——	——	—	—
Argillac. marl, dry -	46	27	25 †	——	—	—
Fullers earth -	53	18	5	3	4	17 ‡
Pouzzolana - -	57	20	6	——	25	—
Tripoli - -	90	7	——	——	3	—
Pure mica - -	38	28	——	20	14 ‖	—
Martial mica -	34,5	25,5	——	18	22	—
Roof ſlate or ſhiſtus	46	26	4 mild	8 mild	14	—
Flagſt. or argill. ſhiſt.	36	56	——	——	4	—
Horn-ſtone - -	37	22	2	16	23	—
Killas - - -	60	25	——	9	6	—
Toadſtone - -	63	14	7	——	16	—
Zeolyte - -	60	20	8	——	—	12 §
Pitch-ſtone -	65	16	——	——	5	14 ¶

Gronſten	-	- Horn-ſtone and mica, or horn-ſtone and ſhoerl.
Stellſten	-	- Mica, quartz and argill.
Binda	-	- Horn-ſtone, mica, ſhoerl, quartz, and pyrites.
Growan	-	- Argill. mica, and quartz.

* At a medium, when perfectly dry, 63 ſiliceous——† Mild at a medium. ‡ And marine acid at a medium.——‖ White calx of iron.——§ At a medium.——¶ And air.

Siliceous

Siliceous Genus.

100 Parts.	Silex.	Argill	Calcar.	Magn.	Iron.
Cryſtal	93	6	1	—	—
Flint	80	18	2	—	—
Petroſilex	72	22	6	—	—
Jaſper	75	20	—	—	5
Chalcedonian	84	16	—	—	—
Ruby	39	40	mild 9	—	10
Topaz	39	46	ditto 8	—	6
Hyacinth	25	40	dit. 20	—	13
Emerald	24	60	8	—	6
Sapphire	35	58	5	—	2
Chryſopraſium	95	—	1,7	1,2	0,4[a]
Lapis lazuli	—	—	—	—	—[b]
Felt ſpar	67	14	—	8	—[c]
Veſuvian garnet	55	39	6	—	—
Garnet	48	30	12	—	10
Martial garnet	43,6	27,6	10	—	19
Shoerl tranſparent	48	40	5	1	5
Shoerl black	58	27	5	1	5
Bar ſhoerl	61,6	6,6	21,6	5	1,6[d]
Tourmaline	37	45	13	—	5[e]
Baſaltes	52	15	8	2	25
Rowley ragg	47,5	32,5	—	—	20
Comp. and cellular lava	47	30	5	—	18
Vitreous ditto	49	35	4	—	12
Another from Lapari	69	22	—	—	9
Black agate of Iceland nearly as the above	—	—	—	—	—
Pumice ſtone	84 or 90	—	—	6 to 11	—[f]
Martial muriatic ſpar	50	—	—	30 mild	20[g]
Turkey ſtone	70	5	mild 25	—	—[h]
Ragg ſtone	70	5	dit. 20	—	5[i]
Siliceous grit, with calcareous cement	62,5	—	do.37,5	—	—
Siliceous ditto, with argillaceous cement	77	20	—	—	3[k]
Ditto, with ferruginous cement	80	5	—	—	15[l]

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[a] 0,6 copper, and ſparry acid.——[b] 80 martial fluor, 20 gypſum, as I believe.——[c] 11 ponderous.——[d] 5 water.——[e] At a medium. [f] Remainder calcareous.——[g] As I believe.——[h] As I believe. [i] As I believe.——[k] As I believe.——[l] As I believe.

Siliceous Genus continued.

Granite - -	Quartz, felt ſpar and mica. Quartz, felt ſpar and ſhoerl.
Stellſten - - Granitello - -	Quartz and mica.
Rapakivi - - Granitone - -	Felt ſpar and mica.
Murkſten - - Norka - - -	Quartz, garnet, and mica.
Porphyry - -	Jaſper, chert, lava, ſhoerl containing quartz, felt ſpar, ſhoerl, mica, or ſerpentine in a cryſtalline form.
Pudding ſtone - -	Jaſper, chert, ſiliceous grit, or lava, containing pebbles of an oval form.
Siliceous breccias -	The ſame ground and contents, but in angular forms.
Gneiſs - - - -	Quartz, mica, ſteatites. Quartz, mica, ſerpentine. Quartz, mica, ſhoerl, ſteatites, or ſoap rock. Quartz, felt ſpar, mica, ſerpentine.
Amygdaloides - -	Jaſper, or chert, containing ſpar or ſerpentine.
Metallic rock of Born	Quartz, clay, and ſteatites, and felt ſpar ſometimes.
Variolite - -	Serpentine, containing various ſtones.

Proportion of Ingredients in Natural Salts.

Salts.	Acids	Alka.	Earth	Water.	
Tartar vitriolate -	31	63	—	6	
Glauber's ſalt -	14	22	—	64	
Vitriolic ammoniac	42	40	—	18	
Epſom - -	24	—	19	57	
Alum - -	24	—	18	58	
Vitriol of iron -	20	—	—	55	25 iron.
Ditto of copper -	30	—	—	43	27 copper.
Ditto of zinc -	22	—	—	58	20 zinc.
Nitre - -	30	63	—	7	
Cubic nitre - -	29	50	—	21	
Nitrous ammoniac	46	40	—	14	
Nitrous ſelenite -	33	—	32	35	
Ditto Epſom -	36	—	27	37	
Salt of Silvius -	30	63	—	7	
Common ſalt -	33	50	—	17	
Sal ammoniac -	52	40	—	8	
Marine ſelenite -	42	—	38	20	
Borax purified -	34	17	—	47	

INDEX.

A.

ACHROMATIC teleſcope, 269
Acids, 124
Acid, acetous, 460, 482
Acid of amber, 198
Acid of ants, 523
Acid of apples, 431
Acid, arſenical, 211, 359
Acid of benzoin, 435
Acid of borax, 193
Acid of camphor, 451
Acid of cork, 451
Acid of fat, 516
Acid of galls, 432
Acid of lemons, 428
Acid, marine, 173
Acid, dephlogiſticated marine, 176
Acid of milk, 492
Acid of molybdena, 215
Acid, nitrous, 151, 156
Acid of phoſphorus, 204
Acid, Pruſſian, 303
Acid of ſilk worms, 504
Acid of ſpar, 196
Acid of the ſtone of the bladder, 507
Acid of ſugar, 444, 449—empyreumatic, 447
Acid of ſugar of milk, 496
Acid of tartar, 441—empyreumatic, 446
Acid of tin, 337
Acid of tungſten, 216
Acid, vitriolic, 140
Acid of wood, empyreumatic, 447
Adamantine ſpar, 108
Aggregation, 74
Air, alkaline, 123
Air, fixed, 183
Air, hepatic, 139
Air, inflammable, 95
Air, marine, 173
Air, nitrous, 94, 159
Air, phoſphoric, 205
Air, vital, 94
Air, vitriolic, 144
Alembic, 36
Alembroth, 262
Algaroth, 380
Alkali, 114
Alloys, 131
Alum, 142
Amalgam, 265
Amber, 198
Ambergris, 508
Ammoniac, ſal, 120, 175
Analyſis, 1
Animals, 411
Antimony, 263, 378
Aqua regia, 180
Arſenic, 212, 356
Aſſaying, 130
Aſphaltum, 402
Atmoſphere, 93
Attraction, 2, 3, 71, 78
Aurum muſivum, 342

B.

Balance, 59
Balſams, 139
Barbadoes tar, 402
Barytes, 105
Bath, 38
Beer, 464
Benzoin, 434
Bell metal, 285
Bezoar mineral, 380
Bile, 520
Biſmuth, 349
Bleaching, 177, 499
Blood, 510
Blow-pipe, 43
Bones, 519
Borax, 191
Braſs, 288
Bread, 461
Bronze, 285
Butter, 497

INDEX.

C.

Calamine, 376
Calcination, 33
Calomel, 261, 263
Camphor, 423
Candles, 500
Caſſius, powder of, 225
Celſius, 30
Cementation, 34
Ceruſe, 270
Charcoal, 185, 454
Cheeſe, 494
Chemiſtry defined, 1
Cinnamel, 264
Coating, 38
Cobalt, 366
Colcothar, 300
Colouring matters, 425
Combination, 74
Combuſtion, 32, 94
Concentration, 34
Crawford, Dr. 11
Copper, 278
Cream, 497
Crucibles, 35
Cryſtallization, 81, 128
Cucurbits, 35
Cupellation, 231

D.

Detonation, 154
Diamond, 405
Digeſtion, 34
Diſtillation, 34, 452
Dutch gold, 288
Dying, 426

E.

Earths, 99
Eggs, 497
Eliquation, 273
Elements, 75
Elutriation, 345
Eolipile, 97
Ethers, 472
Ethiops mercurial, 264
Eudiometer, 162
Evaporation, 34
Excrement, 507
Extenſion, 71

F.

Fahrenheit, 30
Fat, 516
Fermentation, 457
Fleſh, 514
Flour, 419
Freezing, 18
Fuel, 38
Fulminating powder, 156
Furnaces, 37
Fuſion, 34

G.

Gaſtric fluid, 522
Glaſs, 120
Glue, 513
Gluten, vegetable, 420
Gold, 221
Gravity, 72
Grotto del Cano, 184
Gum, 417
Gunpowder, 154
Gypſum, 104, 143

H.

Hair, 505
Heat, 2, 5, 87
Homberg's phoſphorus, 175
Honey, 498

I.

Jargon of Ceylon, 110
Jelly, 513
Jet, 402
Inertia, 71
Inflammation, ſpontaneous, 165, 310,
341, 392
Ink
Integrant, 74
Iron, 293

K.

Kermes mineral, 382
Kier, his acid, 169, 241
Koumiſs, 465

L.

Lac, 502
Lead, 268
Libavius; fuming liquor of, 338
Light, 87
Litharge, 269
Liver of ſulphur, 137
Luna cornea, 238
Lunar, cauſtic, 238
Lutes, 39

Magneſia,

M.

Magneſia, 106
Magiſtery of biſmuth, 350
Malt, 464
Manganeſe, 386
Matraſs, 35
Mercury, 256
Metals, 85, 127
Metheglin, 465
Milk, 491
Mines, 129
Minium, 268
Mixture, 74
Molybdena, 215

N.

Nickel, 353
Nitre, 151
Nooth, Dr. 54

O.

Oils, fat, 420
—— volatile or eſſential, 422
Orpiment, 358

P.

Parting, 232
Peat, 402
Petroleum, 402
Pewter, 343
Phoſphorus, 200
Phlogiſton, 89, 93
Pit-coal, 402
Pitch-blende, 398
Platina, 251
Plumbago, 326—332
Polarity, 81
Precipitate per ſe, 256, 265—red, 259
Precipitation, 77
Principles, 75, 83
Proceſſes, 33
Pruſſian blue, 302
Putty, 346
Pyrites, 135

Q.

Quartation, 232

R.

Realgar, 358
Reaumur, 32
Receivers, 36
Rectification, 34
Regulus, 128
Reſins, 423
Reſpiration, 94
Retorts, 35
Roaſting, 33

S.

Salt, common, 170
Salts, 85
Saturation, 76
Serum, 512
Siderite, 313
Silk, 504
Silver, 236
Smalt, 370
Smell, 424
Soap, 119
Solder, 129, 273
Solvent, 76
Sorrel, ſalt of, 442
Speculum metal, 285
Spelter, 377
Spermaceti, 517
Spirit, ardent, 459, 461, 466
Starch, 420
Steam, 17
Steel, 320
Stills, 36
Stone of the bladder, 506
Sublimation, 34
Sublimate, 35—corroſive, 262
Sugar, 418
—— of lead, 271
—— of milk, 494
Sulphur, 135
Suſpenſion, 75
Syntheſis, 1

T.

Tallow, mineral, 402
Tartar, 437, 461
Temperature, 6
Terms, 4
Thermometer, 10, 16, 23, 102
Tin, 334
Tin plate, 313
Touch-needles, 233
Tree of Diana, 243
Tungſten, 215
Turbith mineral, 258

U, V.

Uranite, or uranium, 398
Urine, 506

Vegetables, 410
Verdigris, 281
Vermilion, 264
Vinegar, 460

W.

Water, 76, 95
Wax, 498
Weights, 65
Welding, 252, 324
Wine, 463
Wolfram, 216, 394
Wool, 505

Y.

Yeaſt, 459, 461

Z.

Zaffre, 370
Zinc, 372

[illegible] 83

24
Z.D. 29/9/6
79